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DEVELOPMENTS IN HYBRID CORN PRODUCTION

BY

G. H. DUNGAN
C. M. WOODWORTH
A. L. LANG
J. H. BIGGER
R. O. SNELLING

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ILLINOIS FARMERS' INSTITUTE
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A cooperative project among the Division of Cereal Crops and Diseases, Bureau of Plant Industry, U. S. Department of Agriculture, the Illinois State Natural History Survey, and the Illinois Agricultural Experiment Station.

DEVELOPMENTS IN HYBRID CORN PRODUCTION*

By

G. H. Dungan, C. M. Woodworth, A. L. Lang, J. H. Bigger and R. O. Snelling[1]

INTRODUCTION

Hybrid corn is an outstanding contribution to the agriculture of the Corn Belt. In all the history of corn production no method of breeding has held out so much promise for the future. The methods of corn breeding have progressively advanced through various phases including (1) mass selection of adapted strains from the diverse kinds brought into the Corn Belt by the early settlers and culminating in types that fulfilled the standards set up by corn judges beginning in the early nineties; (2) special breeding programs including the ear-row method begun at Illinois by the late Doctor C. G. Hopkins in the late nineties, involving selection for special characteristics such as composition, ear height, yield and other qualities; (3) the community yield tests begun shortly before 1920 which set aside the old show standards and put emphasis on field performance, bringing into prominence various mass selected utility types such as Krug corn; (4) mass selection of adapted strains in which special attention was paid to freedom from disease as evidenced by carefully conducted germination tests.

R. O. Snelling **G. H. Dungan** **J. H. Bigger**
C. M. Woodworth **A. L. Lang**

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* Discussion delivered before the 43rd Annual State Meeting, Paris, February, 1938.

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All of these attempts at improvement have shown that from a breeding standpoint corn is very plastic and responsive to selection. However, much was left to be desired in the way of increasing yields, lodging resistance, freedom from disease and other qualities.

In the background another program had quietly been developing in the hands of certain scientists at various experiment stations. The foundations for the new program were laid before 1900 with the work of Beal and others who emphasized the importance of selection on the male as well as the female side, and investigated the possibilities of varietal crosses. The rediscovery of Mendel's laws of inheritance in 1900 stimulated inbreeding and crossing to study the inheritance of certain visible characters. Shull in 1908 and East in 1909 published papers on hybrid vigor in corn. Shull outlined a method for the commercial utilization of hybrid corn that differs only in minor details from that now in use. Its essential features were (1) the isolation of desirable inbred lines which breed true for the characters they possess; (2) the determination of those lines that are the most productive in crosses; and (3) the utilization of the superior crosses in the commercial production of hybrid corn.

Not until 1921 was the first seed of a double-crossed hybrid produced commercially and then the honor went not to a Corn Belt state but to the state of Connecticut, where East, Hayes, and Jones had carried on their breeding experiments and developed hybrids that compared favorably with the best open-pollinated varieties. George Carter of Connecticut had the distinction of growing the first field for the commercial production of double-crossed corn. It was a cross called Burr-Leaming and involved both white and yellow inbred lines, and therefore was a mixture of white and yellow grain.

In the meantime, other investigators were rapidly developing inbred lines in the Corn Belt. The early experimental hybrids involved lines selected on a restricted scale and sufficiently unproductive in the inbred condition as not to warrant an extensive program of hybrid seed production. The inbreeding programs were greatly expanded during the twenties, and in the early thirties, a sufficient number of satisfactory lines were available for commercial production to advance rapidly. Commercial hybrids now are available that distinctly excel the best open-pollinated varieties in yield, lodging resistance and other important characteristics. Thus, for 25 years or more, hybrid corn was quietly building up a substantial background that was to prove so important in its future development.

During the last five years the production of hybrid corn has had a phenomenal expansion. In 1934 only about 5,000 acres in Illinois were planted to hybrid corn. The acreage increased to approximately 35,000 in 1935 and in 1936 to nearly 250,000 acres. For the first time in the history of the hybrid corn program, Illinois farmers planted over a million acres with hybrid seed in 1937. For the 1938 season, it is estimated that more than 5,000,000 acres, slightly more than half the corn land of Illinois will be planted to various corn hybrids.

When inquiry is made into the reasons for this rapid shift from open-pollinated to hybrid corn, it is found that desirable corn hybrids possess certain characteristics that the grower wants his corn to have.

These characteristics are as follows:

1. Higher yield than the best adapted open-pollinated varieties.
2. Stiff stalks that remain erect until harvest.
3. Strong root systems which prevent the plants from lodging during the growing season.
4. Resistance to insects, such as chinch bugs, grasshoppers, southern corn rootworm, corn earworm.
5. Resistance to rots of roots, stalks and ears.
6. High quality of grain for feeding and marketing.
7. Early maturity to enable plants to escape damage from killing frosts in the fall, and yet late enough to occupy the growing season fully.
8. Resistance to injury from early low temperatures in the fall so as to reach maturity in the period of favorable weather which often follows.
9. Capacity to use soil minerals, nitrogen and moisture effectively.
10. Resistance to extremes of heat and drouth in summer.
11. Capacity to perform well in competition with other corn plants when planted thickly.
12. Ability to mature the ear before the stalk and leaves mature.

This list of qualities of good corn hybrids might be extended, but is sufficient to indicate that the development of hybrid corn is progressing along constructive lines. Corn hybrids of many special types can be made by combining parent inbreds which possess the desired characteristics.

BREEDING AND PRODUCTION METHODS FOR CORN HYBRIDS

"Hybrid seed corn, as the term is now commonly used, signifies first generation hybrid seed resulting from cross fertilization involving inbred lines of corn or (and) their combinations; the inbred lines having been self fertilized until they are reasonably pure." This definition occurs on page 6 of Bulletin No. 330, "Rules and Regulations, Illinois Seed and Weed Control Laws," Department of Agriculture, Springfield, Illinois.

The fact that the better corn hybrids aid in stabilizing production, improving quality, and reducing the cost of producing a bushel of corn unquestionably is responsible for the increasing demand for hybrid seed corn. This increased demand, together with reduced supplies in certain years as a result of drouth, has maintained relatively high prices for the available seed stocks. Largely because of this situation many growers have become interested in developing their own inbred lines. While the present seed situation is likely to be very temporary and even though the cost of developing inbred lines is too large to warrant independent breeding programs by small producers, present interest is great enough to justify a somewhat detailed discussion of the methods and procedures involved.

How Inbred Lines Are Produced

"An inbred line," as defined in the rules and regulations of the Illinois Crop Improvement Association, "shall consist of a line of corn that has been developed as a result of not less than five generations of controlled self fertilization." Several years are required for testing in combinations and for multiplying the seed stock to the point where it is commercially useful. Most inbred lines have been inbred at least ten generations before they enter into commercial use, even though there is no doubt of their ultimate value.

In the first generation of inbreeding there is *considerable* variation among the plants and ears within a line, but as the inbreeding progresses uniformity is rapidly approached. The breeder selects the most promising types in each generation and continues their propagation until their worth can be tested in crosses. After about the third selfing, preliminary crosses can be made as an aid to the breeder in his selection.

Performance tests are necessary to determine the combining value of new material. Top crosses and single crosses are used for this purpose. A top cross is a cross between an inbred line and an open-pollinated variety, and a single cross is a cross between two inbred lines. In interpreting results of preliminary tests, yield should not be the only criterion. An inbred line may contribute a good root system, a strong stalk, good grain quality, insect resistance, or still other qualities which in themselves make it useful in a breeding program. While poor, faulty inbred lines may occasionally combine well in crosses they are not very useful, as commercial demands require that an inbred line must be capable of propagation without too much pampering and expense.

In producing inbred lines, the breeder should not select too closely to a preconceived type or he may defeat his own purposes. Inbred lines from unrelated varieties are more likely to produce good crosses than lines from the same or closely related varieties. It is well, therefore, to start the inbreeding program with a wide choice of material so that there may be greater chances of discovering lines that are widely different genetically from each other. Obviously lines with particular characteristics may be obtained most readily from varieties that possess those characteristics. Long-eared inbreds are most likely to come from a long-eared source, and an early line from an early maturing variety, though there are some exceptions to this general situation. This likewise applies in breeding for insect resistance and resistance to heat and drouth, which are very important considerations in certain sections.

A simple system of keeping pedigree records is indispensable in any breeding program. A great diversity of methods is used as is evidenced by the wide divergence in symbols employed to designate the inbred lines now in commercial use. A breeder's ingenuity may suggest a method that is accurate and at the same time not too cumbersome. A common method is to assign ear numbers which may or may not be preceded by a letter indicating the variety used. In succeeding generations additional ear numbers are added, the numbers for each generation being separated by a dash (—). For instance, selfed Reid Yellow Dent ear number 1 may be designated as R1, and 10 ears selfed the second year may be designated as R1-1 to R1-10 inclusive. Ten selfed ears from R1-2 would be designated as R1-2-1, R1-2-2, R1-2-3, etc. This system has many advantages but, in time, the string of numbers gets long and somewhat tedious to record.

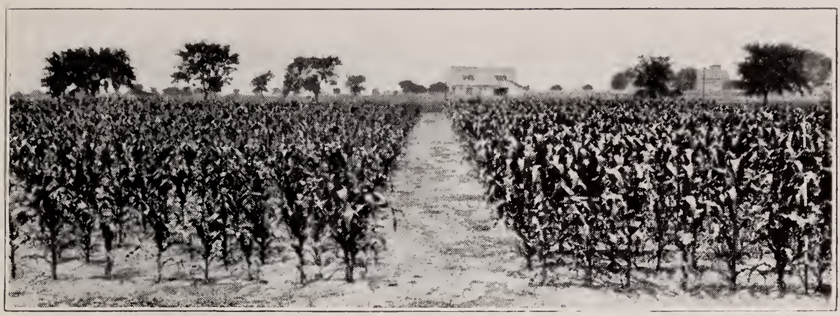


Fig. 1. A breeding plot consisting of various inbred lines and single crosses. Seed is produced in such a plot by hand pollination.

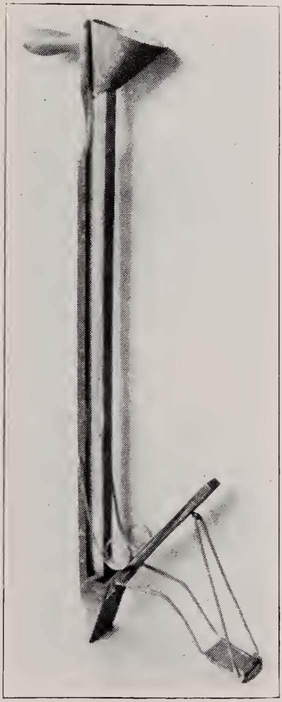


Fig. 2. A convenient hand planter for planting breeding plots. The seed box has been removed and replaced with a tube and funnel for hand planting.

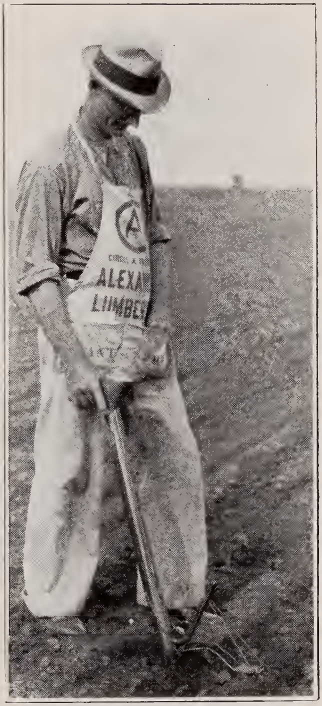


Fig. 3. Planting a breeding plot. A carpenter's apron with rounded corners in the pockets is useful for carrying seed and empty packets.

Another system consists in assigning each ear a number and entering in a pedigree book a more complete description of it. The next year numbers are assigned beginning where those of the preceding year stopped. After each number in the pedigree record the number of the ear from which it came is recorded. This method avoids carrying a long pedigree number on each ear, but requires some time in tracing the pedigree back.

These two numbering systems are the ones in most common use and are mentioned as suggestions. They are both workable and accurate.

Breeding Plots

An increasing number of hybrid corn producers are maintaining breeding plots for the production of new inbred lines, for increasing seed of established inbred lines, and for making experimental single crosses and double crosses. In these breeding plots (Fig. 1) all pollinations must be made by hand, because all ears not hand pollinated will be crossed with other corn growing in the same and adjoining fields.

Breeding plots should be carefully planned in advance to save time and effort during the pollinating season. The strains to be crossed should be planted near one another. It usually is advisable to use short rows and to arrange the rows in series. Material that is to be used repeatedly can be planted in several places so that it will be more accessible. It often is advisable to plant at two different dates in order to spread the pollinating period and increase the chances of bringing at least one of the plantings through unfavorable seasons successfully.

A record should be made, and carefully preserved, of the seed planted in each row. The seed should be put up in small packets marked with the series and row numbers in which they are to be planted, and then arranged in boxes in that order. This helps avoid mistakes and saves time during the rush of the planting season.

Breeding plots preferably should be planted by hand. The field should be marked out in advance in each direction with some type of marker. The seed is generally planted with a jabber planter equipped with a seed tube and a funnel at the top into which the seed can be dropped (Fig. 2). A carpenter's apron is convenient for carrying the seed (Fig. 3). Fewer mistakes will be made if never more than one packet is picked up at a time during the planting operation. If this caution is observed, a pair of rows should be planted to each strain, so that planting can be continuous up one row and back on the other, and envelopes changed at the same end each time. Small wooden stakes are very useful in the breeding plot for marking the rows.

Before the pollinating season begins, the rows should be well marked with substantial labels that will last until after the corn is harvested. A breeding plot is useless unless the rows are well marked with row numbers or with labels giving the actual pedigrees. This can be done with wooden stakes driven in the ground or with durable tags, preferably marked on both sides, fastened to the end plants. It saves steps to have the rows or plots labeled at each end because one will be coming in from either end to make pollinations.

Hand Pollination

In breeding plots where new inbred lines are being produced and established lines maintained, and where crosses are being made under conditions where isolation is not possible, hand pollination is necessary. Hand pollination is also practiced on the inbred line used as a pollen parent in isolated fields where single crosses are being produced. This is done in order to increase the stock of pure seed of that inbred for future breeding work. Hand pollination is also done in the single crosses used as pollen parents in double-crossing plots to produce F_2 seed that can again be used as a pollinator in case of shortage of a sufficient supply of first-generation single-cross seed.

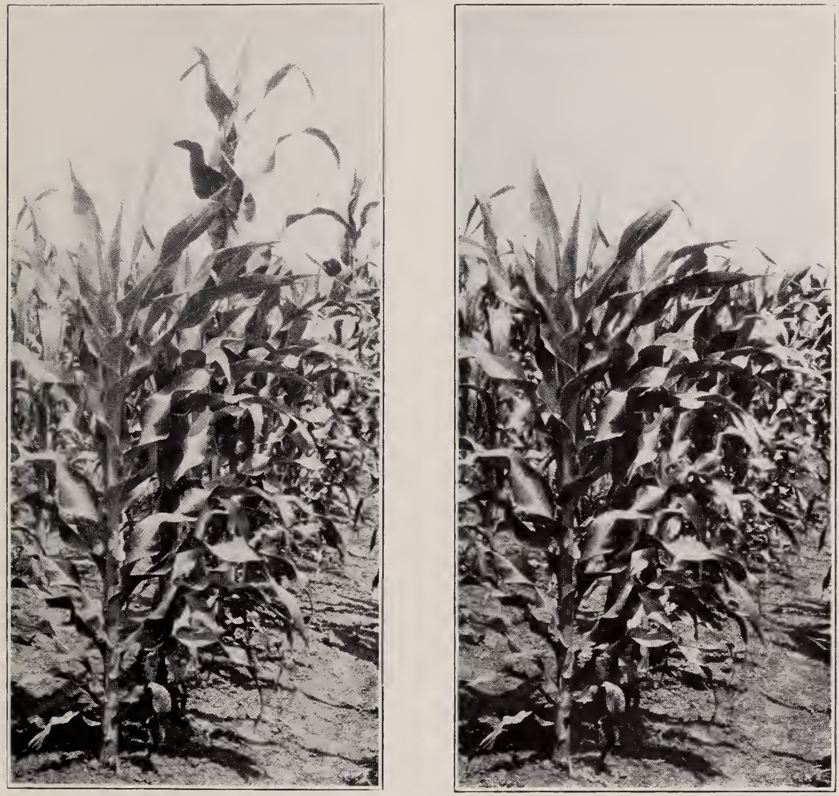


Fig. 4. Inbred lines need to be rogued before the pollinating season begins. Most outcrosses have the vigor of single crosses and are easily detected. These illustrations show an inbred line (left) before and (right) after rogueing.

In the future many producers of hybrid seed will face the responsibility of maintaining their own pure stocks of inbred lines and should develop skill in making hand pollinations rapidly and carefully. Contaminations of inbred stocks with foreign pollen can be noted the following year by the appearance of plants of unusual vigor (Fig. 4). The mistake must not be made of assuming that out-crossed plants are especially good inbred plants. Out-crosses should be rogued out as soon as they can be definitely determined. A good inbred should possess uniformity of plant type (Fig. 5).

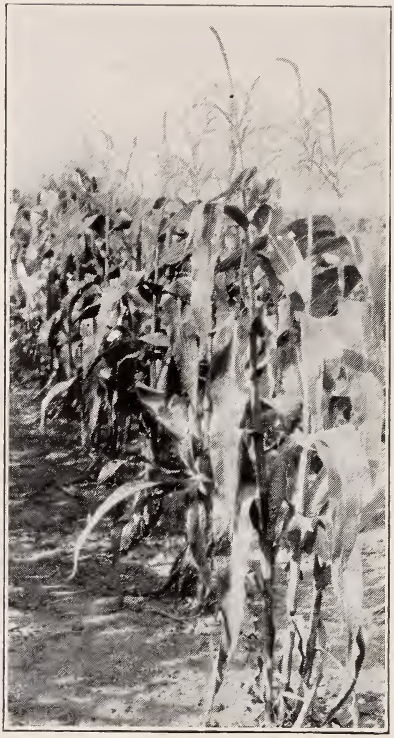


Fig. 5. A good inbred line just after the pollinating season. Note the uniformity of the plants and good plant type.

The accompanying illustrations (Figs. 7 to 10) show approved practices in making hand pollinations. The ear shoots must be protected from contamination with shoot bags before any silks appear. If the husks are long, they can be cut back to encourage a uniform and earlier appearance of the silks. When a suitable tuft of silks appears under the shoot bag, a tassel should be bagged to gather pollen for the pollination. If the plant is to be self pollinated, the tassel of the plant bearing the shoot is bagged; if the plant is to be crossed, a tassel is bagged in the strain that is to serve as the male parent. Tassels usually are covered with bags in the afternoon and the pollinations are made the next morning while the tassels are shedding pollen freely, which begins soon after the dew has disappeared and the air has become dry. A little experience will soon teach the operator how to select a tassel that will shed a good supply of pollen.

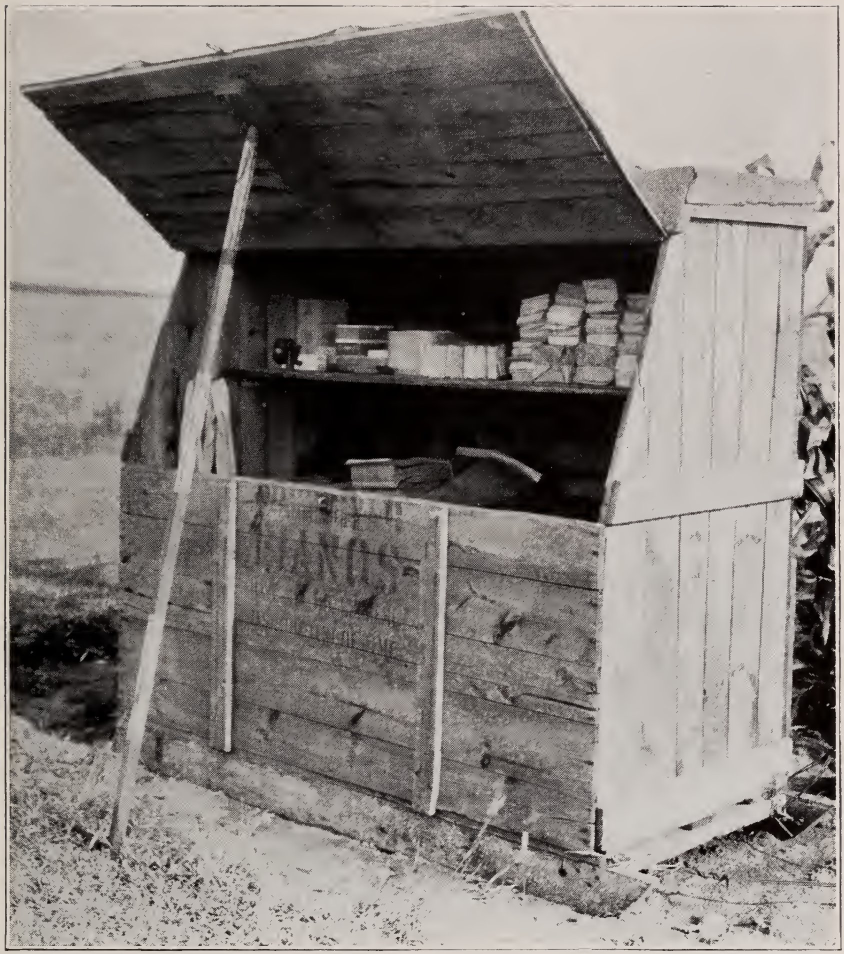


Fig. 6. A piano box covered with roofing paper and provided with a hinged lid and shelves makes a convenient place to store supplies near the breeding plot.

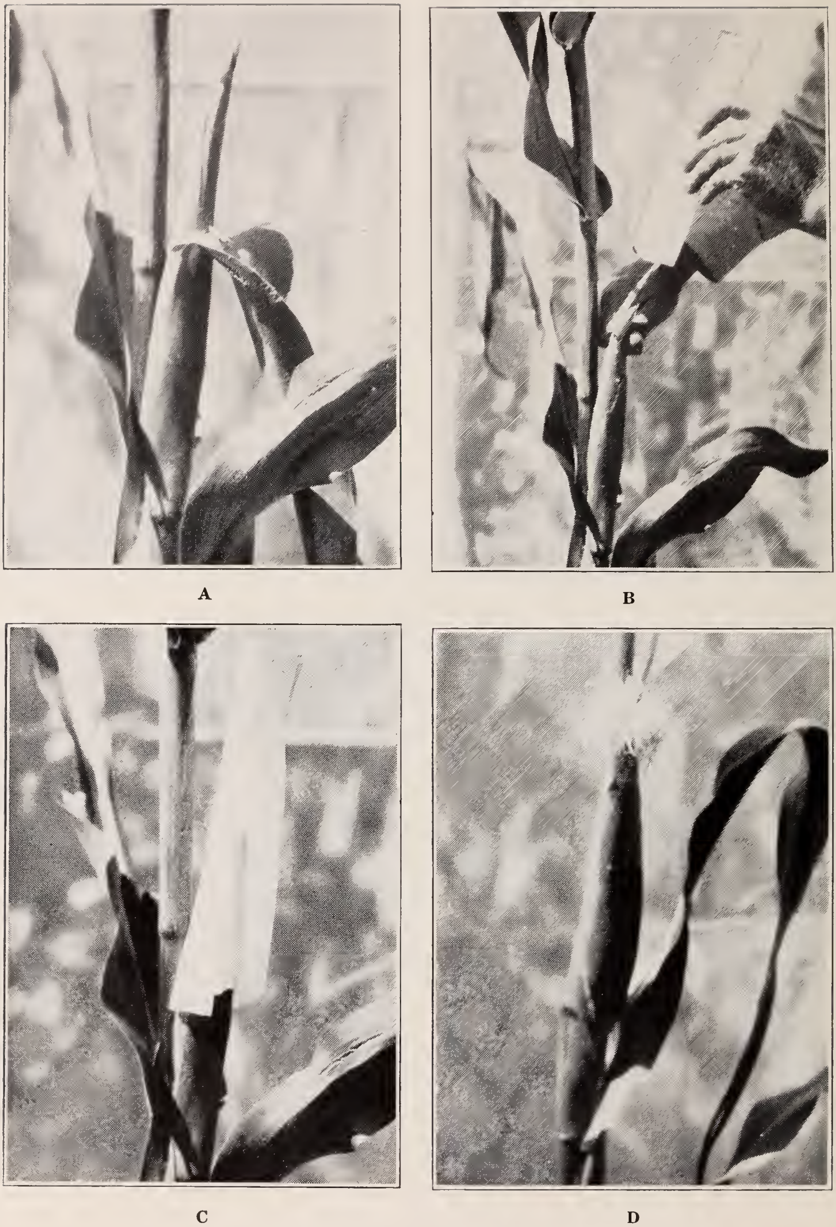


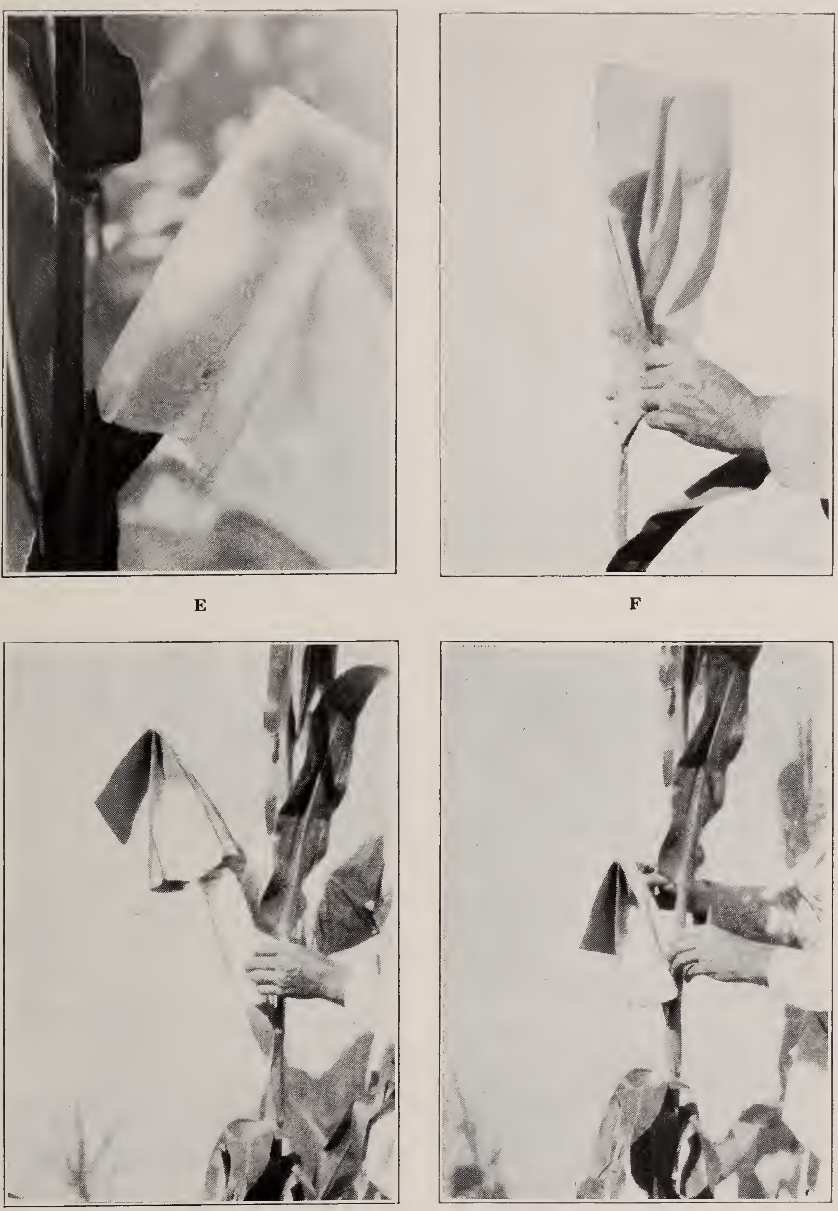
Fig. 7. PROCEDURE IN MAKING HAND POLLINATIONS.

A—Shoot at proper stage for bagging. Silks will probably emerge in another day. Shoots with short husks will silk before they reach this size.

B—Cutting back the husks preparatory to placing the shoot bag. Where the husks are short, cutting back is unnecessary, but it usually encourages an even tuft of silks.

C—Shoot bag in place, pinched securely between the shoot and stalk to hold it in place.

D—A tuft of silks exposed to show about the right stage for pollinating. Beginners are inclined to make their pollinations too early.



E F

G H

Fig. 8. PROCEDURE IN MAKING HAND POLLINATIONS.

E—The appearance of a good tuft of silks through the shoot bag.

F—Fastening the tassel bag over the tassel. The bag should be folded so as to fit snugly around the stalk just below the tassel to prevent loss of pollen. A paper clip keeps it in place.

G—Ready to remove the shoot bag. Notice how the tassel bag is opened to shelter the silks from stray pollen.

H—Ready to tip up the bottom of the tassel bag and shower the pollen down over the silks.

As soon as a pollination is made, the plant should be suitably labeled with a durable tag fastened to the stalk and later to the ear at harvest time. Wooden tree labels or durable paper labels with brass eyelets are satisfactory for this purpose. Copper wire is good for fastening the labels, as it is pliable and will not rust. In rush periods, a temporary record can be written with a soft lead pencil on the bag which protects the pollinated shoot, and permanent labels attached as soon as time permits. In temporary labeling it is sufficient to indicate the pollen parent, but the permanent label should carry the record of the complete parentage. It is customary in recording crosses to record the ear parent first, followed by the pollen parent. For instance, A x Hy, means that inbred A has been pollinated by inbred Hy. The symbol "x" is used to indicate a cross. The most common selfing symbol is an x within a circle ⊗ following the designation of the ear parent. Sib crosses, that is, crosses between different plants of the same inbred line can be marked, "sib x," or "#," following the designation of the ear parent.

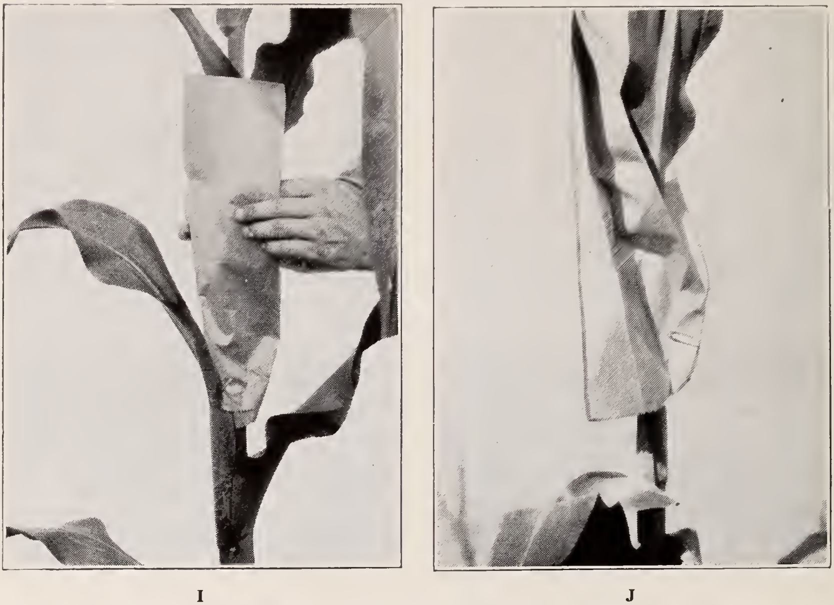


Fig. 9. PROCEDURE IN MAKING HAND POLLINATIONS.

I—Completing the pollination. The tassel bag is shaken to bring down all the pollen.
J—The tassel bag is pulled down firmly over the shoot and is neatly fastened by folding around the stalk. A paper clip holds it in place.

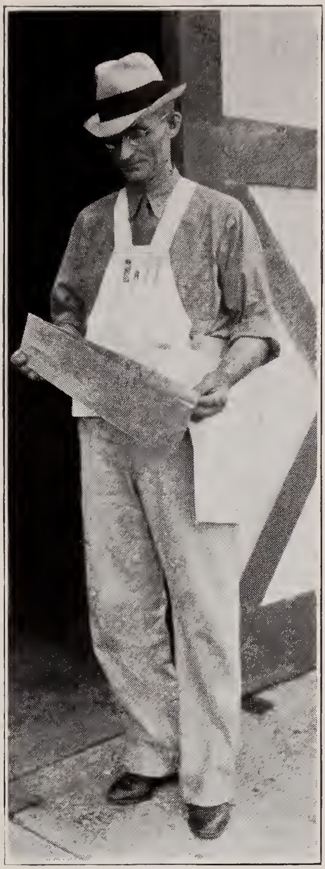


Fig. 10. A convenient apron for use in making pollinations. There is a place for tassel bags, shoot bags, tags, field notebook, pencils and paring knife.

Single Crosses

A single cross is a cross between two inbred lines. When a single cross is produced, the hybrid kernels, of course, are borne upon the inbred line used as ear parent and therefore resemble, in appearance, the selfed or sib-crossed ears and kernels of that line. It follows, then, that the yield of seed of a single cross will be approximately the yield of the ear parent line. This varies for different inbreds, of course, but in general, is low, and consequently single-crossed seed is expensive to produce.

When inbred lines are crossed the vigor reduced during the inbreeding process is regained. In certain fortunate combinations the resulting vigor may exceed that of the open-pollinated variety or varieties from which the parent lines originated. Single crosses as a class are extremely uniform. All of the plants within a particular combination are alike in practically all characters of the plant and ear. This is to be expected because the parents are relatively pure, and consequently all the F_1 plants have the same genetic constitution. Productive combinations, therefore, gain a considerable advantage from this fact as every plant produces a good ear and thus contributes to the total yield of the hybrid. In addition to uniformity and high yield, the better single crosses generally have good seed quality and are resistant to lodging and disease.

Three-Way Crosses

A three-way cross involves three inbred strains. Two of these are combined to make a single cross, and this is then crossed with a third inbred line. The single cross usually is used as the ear parent, as the yield of seed is much greater than if the line were the ear parent, and the seed is larger, better filled and better suited to handling in corn-planting machinery.

Three-way crosses are less uniform in their plant characteristics than single crosses but more uniform than double crosses. The disadvantage of the three-way cross lies in the use of an inbred line in place of a single cross as the pollen parent. The line is less vigorous, sheds less pollen, and yields less than a single cross, and may be affected

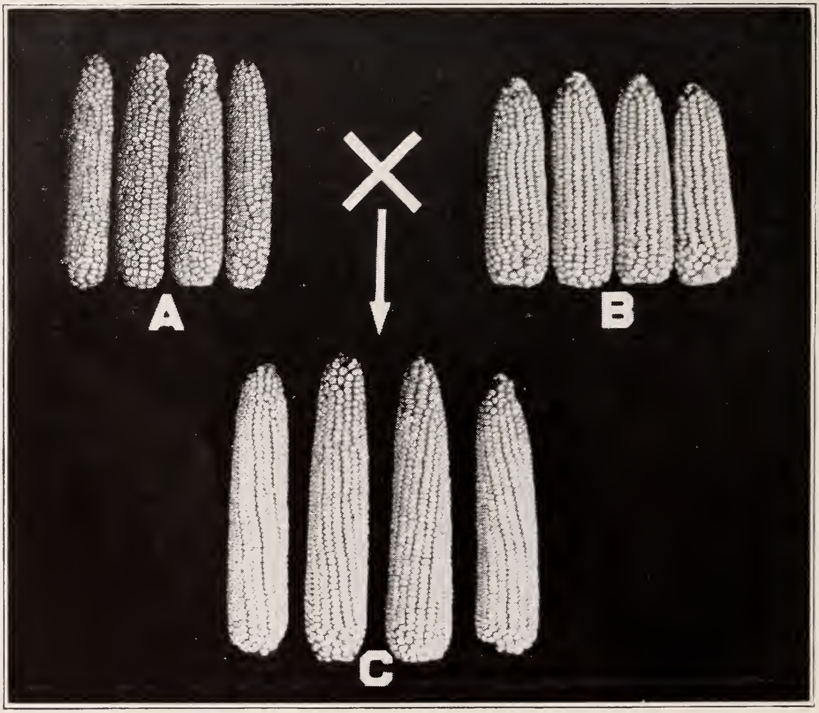


Fig. 11. The foundation breeding material necessary to make up a double cross, in this particular instance Illinois Hybrid 960. A and B are Inbreds R4 and Hy respectively, with the single cross, R4 x Hy, represented by C below.

more adversely by unfavorable growth conditions than a single cross. Until recently a large proportion of the commercial seed of hybrid corn consisted of three-way crosses, but at the present time practically all of the hybrid seed offered for sale is double-crossed seed made by bringing together four lines instead of three.

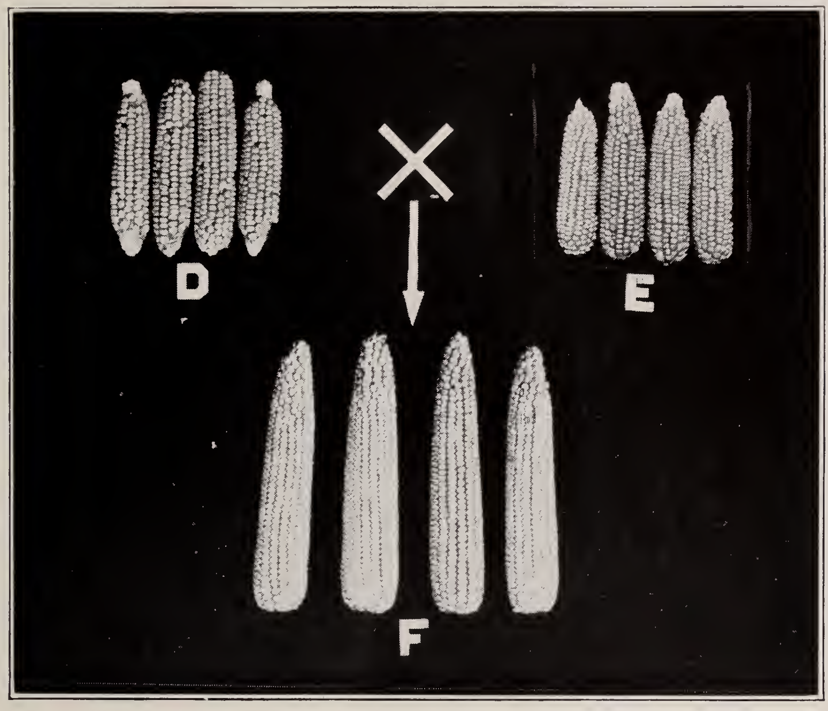


Fig. 12. D and E are inbreds L317B2 and ITE701 respectively, with the single cross, L317B2 x ITE701, represented by F below. R4 x Hy pollinated by L317B2 x ITE701 makes the commercial seed for Illinois Hybrid 960. The hybrid is not changed if the single crosses are made in reverse order, Hy x R4 or ITE701 x L317B2.

Double Crosses

Double crosses are derived from four different inbred lines. In producing a double cross, two inbreds, for example A and B are crossed, and two other inbreds, C and D likewise are crossed, thus producing two different single crosses. Then these two single crosses are crossed to produce the double cross (Figs. 11 and 12).

Double crosses have certain advantages over single crosses and three-way crosses. Their greatest advantage lies in the greater ease and lower cost of seed production. The plants within a double cross usually are more variable as to type, time of flowering, time of maturity and other characters than is the case with single crosses or three-way crosses. This may be an advantage in some seasons by permitting a portion of the plants to escape short periods of particularly unfavorable conditions.

Commercial Production of Hybrid Seed Corn

Hybrid seed corn is produced commercially in isolated crossing fields in which the two parents are planted in alternate rows or blocks of rows. Usually single rows of the pollen parent are planted between blocks of two or three and sometimes four rows of the ear parent. The plants in the ear parent rows are detasseled before the tassels have shed pollen. Thus, the seed produced on the detasseled plants is hybrid and the seed produced on the pollen parent plants is sib-pollinated seed of that parent.

Isolation from Other Corn

The crossing plot or field should be separated from other corn to avoid contamination from foreign pollen. Fields in which single crosses are being produced should be isolated at least 40 rods in all directions. Even greater isolation is desirable. An abundance of pollen of the right kind available just when needed is itself a protection against contamination. However, as inbred lines do not produce as much pollen as hybrids or open-pollinated varieties, this protection is not provided in single-crossing plots, and hence greater distance from other corn is required.

Fields in which double crosses are being produced also should be isolated from other corn, but the distance can be modified by two conditions that influence the amount of available pollen of the right kind; namely (1) the size of the crossing field and (2) the number of border rows of pollen parent on the side or sides nearest other corn. A table giving these modifications is contained in the rules and regulations for certifying hybrid corn, published by the Illinois Crop Improvement Association.

Planting the Crossing Field

As stated above, two kinds of corn to be crossed are planted alternately in the crossing field. Experience indicates that one row of the pollen parent to two or more rows of the ear parent is satisfactory in most cases. However, this ratio may have to be modified, depending on the strains used as pollen parents. In the case of certain inbred lines, pollen production may be sufficient for only one row of the ear parent. Instead of changing the ratio, other devices may be used such as thicker planting of the pollen parent, or thinner planting of the ear parent, or both, or the rows may be planted closer together than the usual distance. Drilling the seed in the row instead of planting in hills may also aid in obtaining better pollination. The larger the proportion of the crossing field which may be devoted to ear parent, the larger will be the production of hybrid seed per unit area and hence the lower the cost per bushel. In the case of single crosses interplanted to produce double-cross seed it is feasible to use a ratio of one row of pollen parent to three rows of ear parent. Hybrid seed is thus produced on three-fourths of the field.

The actual planting of the double-crossing plot requires very little extra trouble over straight planting. If the plot is small (an acre or less) it can be planted by hand with a common jab planter, the only extra requirement being that the hills and rows be marked off before-hand. If a two-row machine planter is used, the ratio being 1 pollen to 3 ear-parent rows, the seed in one box will have to be changed from pollen parent to ear parent and from ear parent to pollen parent every half round. The same proportion of pollen parent to ear parent can be obtained (but in the order 1-2-1-4-1, etc.) by using two separate two-row planters. One of these carries seed of the ear parent in one box and seed of the pollen parent in the other; the other planter carries seed of the ear parent in both boxes. On every trip across the field the first planter precedes the second. There is no changing of seed in this scheme, but care must be taken to refill the boxes with the right kind of seed. This particular order of planting can be more easily and simply done by using a four-row planter, one of the middle boxes carrying seed of the pollen parent and the other three boxes carrying seed of the ear parent.

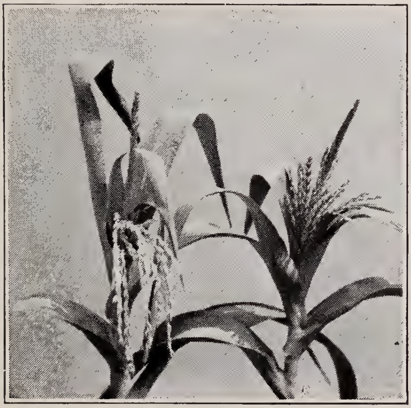


Fig. 13. Tassels at the right stage for pulling. All the tassel branches can be grasped and cleanly removed.

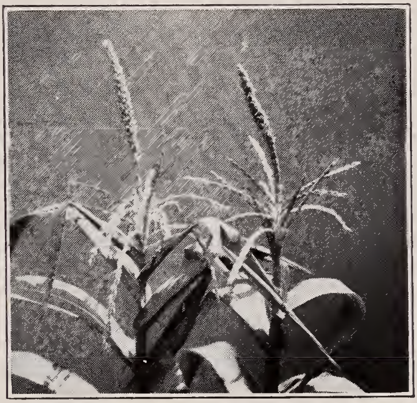


Fig. 14. Tassels that have been left one day too long. The central spike has begun to shed pollen.

The above comments apply to planting the body of the field. On the sides, solid plantings of one to many pollen rows may be made, depending on the number of border rows needed to meet the isolation requirements. Planting pollen-parent seed along the ends of the rows is not desirable as it is sometimes difficult to distinguish at detasseling time between pollen- and ear-parent plants when they are mixed as would likely be the case at the ends of the rows. Of course, if pollen border rows are needed across the ends to protect against contamination from an adjacent field, there is no choice, and the planting must be done so that the plants of the pollen parent are far enough removed from those of the ear parent to make separation easy.

Detasseling the Ear Parent

The tassels borne on the ear-parent plants should be removed before they shed any pollen (Figs. 13 and 14) in order to insure that the silks on these plants will be pollinated by pollen from the male parent only. The job of detasseling should be thoroughly done and this necessitates going over the plot at least every other day and preferably every day to remove tassels. The tassels should be pulled out, not cut off. If possible to avoid it, no leaves should be removed with the tassel. It is well to grasp the stalks at the top leaf sheath with the left hand and pull out the tassel with the right hand. Care must be taken that the whole tassel is removed—that no branches of the tassel are left in the boot to be exserted later and shed pollen.

The detasseling period varies in length depending upon the hybrid or line and the weather conditions. Ordinarily it lasts 10 to 20 days. Uniform inbred lines usually have a rather short period during which pollen is shed. Late plants and tillers or suckers may considerably extend the detasseling period. However, most inbred lines produce very few or no suckers. In some seasons the soil is dry at planting time, and many kernels do not germinate until it rains, resulting in late-flowering plants. Such plants have to be watched and tassels removed before pollen is shed.

There are several reasons why every tassel on the ear parent should be removed. Certification requirements permit that the sib-pollinated seed of the inbred line used as pollen parent of a single-crossing plot may be used as ear parent the following generation. A poor job of detasseling may result in considerable contamination of this seed and require an unnecessary amount of rogueing the following generation. Hence, for the production of single-cross seed using inbred lines as parents, the goal should be nothing short of perfect detasseling. In the case of double-crossing plots, the same thoroughness of detasseling should be the ideal to strive for. The hybrid seed produced on the detasseled rows is used for commercial planting. Pollen shed by an over-locked tassel may self pollinate the ear parent resulting in plants that, on the average, yield about two-thirds as much as the double cross.

Miscellaneous Considerations

Experience indicates that mixtures accumulate in inbred lines in spite of careful handling. This necessitates frequent return to hand-pollinated seed. The regulations of the Illinois Crop Improvement Association require that seed of inbred lines used to produce single crosses shall be no more than two years removed from hand pollination. While it would be desirable to use only hand-pollinated seed for the pollen parent of single-crossing plots, this is not always feasible because of the cost of the seed. A recommended procedure consists in planting isolated single line increase plots with hand-pollinated seed, using the sib-pollinated seed from these plots for one generation as pollen parent of a single-crossing plot, and using the sib-pollinated seed from the pollen-parent rows for the next generation as ear parent for single-crossing plots.

Isolated single-line increase plots and crossing plots in general should be planted only on clean ground. Volunteer corn plants in an isolated plot are a serious source of contamination. They are most likely to occur on old corn ground or on land that has had an application of manure containing corn.

For the production of single-cross seed, special pains should be taken to see that the highest yields possible of high quality seed are obtained. The crossing plot should be made as fertile as possible. The rate of planting should be as high as the soil will support. The rows may be closer together than is the ordinary practice, and the kernels may be drilled in the row instead of planted in hills. Drilling facilitates rogueing out the off-type plants. The seed should be treated with a dust treatment so as to obtain the highest germination possible and make conditions most favorable for growth of the seedling. In seasons of drouth, facilities for irrigating the plot would insure against partial loss or complete failure.

The producer of double crosses does not need to produce the single crosses if he can obtain them from a reliable source by contractual arrangement or by outright purchase. With increase of seed supplies of useful inbreds these sources are developing rapidly. Production of single crosses must be looked upon as a specialized business requiring meticulous attention to detail and a thorough knowledge of the characteristics of the inbreds.

The two main items of expense in double-cross seed production are (1) cost of foundation hybrid seed and (2) detasseling. All other items of cost would apply equally well to seed of ordinary varieties. Compensating for this added cost is the fact that a higher proportion of the crop can be used for seed than of an ordinary variety. This is true even though only three-fourths of the field produces hybrid seed. All sound ears free from disease and of good germination can be used for seed, because they all have the same parentage.

Breeding for Insect Resistance

In a program of corn breeding which involves the selection of inbreds having desirable characteristics, the quality of insect resistance should not be overlooked. Insect damage is serious enough to the corn crop of Illinois to justify a special breeding program for insect resistance. Because of the need for progress in this phase of corn improvement, considerable space in this bulletin is devoted to a discussion of the seriousness of the injury caused by a few of the corn insects prevalent in the central part of the Corn Belt.

The difference in the response of different corn hybrids to insect attack is becoming widely recognized. In some sections of Illinois the reaction of a hybrid to insect attack may determine the suitability of the hybrid to that section. Insect resistance is known to be heritable, and desirable hybrids can be developed which may be relatively unattractive to certain kinds of insects or which may tolerate more injury than average.

The corn-leaf aphid (*Aphis maidis* Fitch) does not cause spectacular damage and for that reason oftentimes is not considered a serious pest. The damage done by this insect may be of minor importance in many instances, but under adverse growing conditions the presence of a heavy aphid infestation is another factor that prevents maximum development of a corn plant. Aphids can be a serious factor in the production of hybrid seed corn. There have been cases in Illinois where aphids have threatened single-crossing fields. In these cases the aphid infestation was so heavy in the tassels of the pollen parent that normal shedding of pollen was prevented. Such a condition results in poor pollination of the ear parent and consequently lowered yields of high priced single-crossed seed.

In 1937 some data were collected for the purpose of determining in just what way the southern corn rootworm (*Diabrotica duodecimpunctata* Fab.) is serious. Six fields planted to open-pollinated varieties of corn and in which there was considerable lodging due to rootworm infestation were sampled in this study. Three of the samples came from fields of Reid Yellow Dent and one each from fields of Station Yellow Dent, Thomas White Dent, and Krug. Three of the fields were located in Illinois and three were located in Indiana. In each field the ears were harvested from 25 erect plants, from 25 plants lodged at a 45 degree angle, and from 25 plants lodged at a 90 degree angle, or flat on the ground. The data obtained are recorded in Table 1. These data indicate that serious rootworm lodging can reduce corn yields nearly 50 percent, and as the yield is decreased, the percentage of damaged kernels is increased. Lodging does not appear to influence the shelling percentage but it does tend to lower the test weight per bushel. The moisture percentage of corn from lodged plants was higher than that of corn from erect or standing plants. This is attributed to delayed maturity of plants that have suffered root damage. If lodging takes place before pollination has been completed, the percentage of poorly filled ears is increased. Ears from lodged plants average smaller in size than those from erect plants. Lodging reduces both the length and the diameter of the ear.

TABLE 1.—The Effect of Different Degrees of Lodging Caused by Southern Corn Rootworm Injury.[1]

Criteria.	Position of plants.		
	Erect.	45° Lodging.	90° Lodging.
Shelled corn—pounds	15.7	12.8	8.0
Unsound corn—percent	0.3	0.8	4.1
Shelling percentage	83.4	80.6	82.6
Moisture percentage	19.0	22.4	25.4
Test weight	58.2	58.0	55.6
Poorly filled ears—percent	2.0	32.0	50.0
Length of ear—inches	9.0	7.9	6.5
Diameter of ear—inches	2.1	2.0	1.8

[1] *Diabrotica duodecimpunctata* Fab.

Corn rootworm injury, like aphid injury, can be especially serious in the production of single-crossed seed. Inbred plants are weak and lack vigor, a condition which results in greater rootworm damage. Yields of single-crossing fields have been lowered in several instances by this insect. If a susceptible inbred is used as the pollen parent, poor fertilization of the seed parent results when the pollen parent lodges before pollination is completed. Poor pollination of the lower side of the ear usually results if lodging of the ear parent occurs before pollination is completed.

Corn earworm (*Heliothis obsoleta* Fab.) damage is well known. Early season damage lowers both the quality and the yield of seed produced. Often such damage is accompanied by ear rots which magnify earworm damage. Late season damage results in a direct loss of kernels and in a damaged seed coat to kernels that remain on the cob.

Chinch bugs (*Blissus leucopterus* Say) can be a serious pest in seed production. However, this insect differs from the southern corn rootworm in that damage usually comes after pollination has been completed. Thus, it is possible to use a chinch bug-susceptible pollen parent, while it is not advisable to use a rootworm-susceptible pollen parent. However, the ear parent should have a rather high degree of chinch bug resistance. Chinch-bug damage reduces yields and causes poor quality seed.

In breeding for insect resistance in corn the ideal would be to develop inbred lines which have resistance to all of the major corn insects. It may be possible to get this resistance into one inbred, but such an accomplishment will be the result of years of patient effort. However, this does not mean that hybrids resistant to several insects cannot be produced until this ideal is attained. Several inbreds available at present, while apparently not possessing resistance to all corn insects, do show a high degree of resistance to one and in some cases more insects. Thus, by making crosses between lines that contribute resistance to different insects it is possible to develop hybrids which will resist most of the major corn insects. Experimental data have been obtained which indicate that there is little association between the factors that cause resistance to different insects. That is, if an inbred line has resistance to one insect it may or may not have resistance to some other insect. This fact makes it more difficult to obtain a line with resistance to many insects, but this does not mean that such a development is impossible. The plant breeder can be encouraged in such an undertaking by the fact that resistance to one insect does not seem to be associated with susceptibility to some other major insects.

PERFORMANCE OF HYBRIDS AND OPEN-POLLINATED VARIETIES

The value of inbreds in a breeding program can be measured only by combining them into hybrids and then testing the performance of these hybrids in the field. Such tests have been conducted in Illinois through four seasons. They involved a relatively large number of fields and represented the major climatic areas and soil types of the state. The detailed results of these experiments have been published in Illinois Agricultural Experiment Station Bulletins 411, 427, 429, and 440.

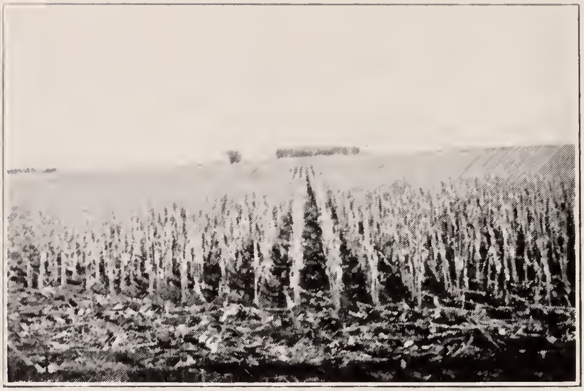


Fig. 15. A commercial field of hybrid corn as it appeared in mid-November, 1937. This field was being harvested with a mechanical picker as may be observed from the broken stalks at the left.

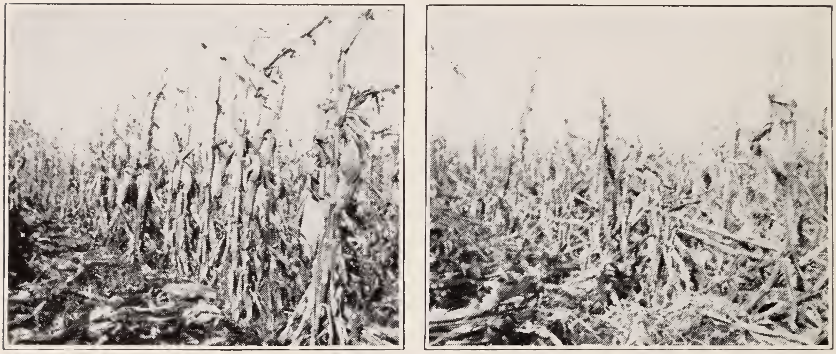


Fig. 16. Views of the edge of two corn plots on the day they were harvested, November 9, 1937. The corn on the left had an erect plant percentage above the average and that on the right was much below the average in percent of erect plants. The yield per acre of the better standing entry was 12 bushels more than that of the other.

Since the results of recent tests are of great interest, a summary of the 1937 tests is presented in some detail here followed by the average of the four years' tests in a condensed form.

Summary of 1937 Tests

In 1937 the tests were conducted on 17 fields representing eight different corn producing areas of the state. In each field, except at Golconda, five adapted open-pollinated varieties were grown along with the many hybrid entries. The average performance of the five open-pollinated varieties has been used as a standard with which to measure the value of any particular hybrid. In order to see how much progress has been attained, the five best hybrids have been averaged and compared with the average of the five open-pollinated varieties in the same field. Table 2 presents this comparison in respect to sound yield and percent of erect plants.

The average yield of the five open-pollinated varieties on all the fields was 73.1 bushels an acre and that of the five best hybrids was 86.7 bushels or 13.6 bushels more. The five open-pollinated varieties at harvest time were standing 49.7 percent, whereas the best hybrids were standing 71.7 percent.

TABLE 2.—Summary Comparison of the Five Best Hybrids with the Five Open-Pollinated Varieties in Respect to Yield of Sound Corn and Percentage of Erect Plants, 1937 Corn Performance Tests.

Location.	Acre Yield of Sound Corn.			Erect Plants.	
	Average of five open-pollinated varieties.	Amount by which the five best hybrids exceeded the open-pollinated varieties.		Average of five open-pollinated varieties.	Average of five best hybrids.
	Bushels.	*Bushels.*	*Percent.*	*Percent.*	*Percent.*
Northeastern Illinois					
Libertyville	54.6	14.4	26.4	60.0	84.4
Northern Illinois					
Stockton	69.9	16.4	23.5	37.9	61.4
Kings	72.1	19.0	26.4	36.0	60.0
Plainfield	77.5	8.9	11.5	89.1	98.1
Average	73.2	14.8	20.2	54.3	73.2
North-Central Illinois					
Cambridge	104.0	15.7	15.1	29.0	71.0
Henry	77.3	14.7	19.0	36.0	75.0
Dwight	59.9	14.6	24.4	52.0	75.4
Average	80.4	15.0	18.7	39.0	73.8
Central Illinois					
Adair	92.7	16.6	17.9	47.9	80.6
Stanford	91.8	18.9	20.6	43.0	69.8
Armstrong	66.8	12.8	19.2	74.2	89.8
Brocton	75.8	8.7	11.5	65.6	82.4
Average	81.8	14.3	17.3	57.7	80.7
South-Central Illinois					
Jacksonville	88.3	17.4	19.7	53.0	78.6
Sullivan	104.3	15.7	15.1	46.9	69.4
Average	96.3	16.6	17.2	50.0	74.0
Southern Illinois					
Alhambra	55.0	8.1	14.7	23.0	39.4
Edgewood	13.0	4.7	36.2	22.3	38.6
Average	34.0	6.4	18.8	22.7	39.0
Southeastern Illinois					
Albion	81.9	10.8	13.2	52.1	81.8
Extreme Southern Illinois					
Golconda	57.8[1]	13.3	23.0	77.5[1]	64.2
Average from all fields	73.1	13.6	18.6	49.7	71.7

[1] Average of two open-pollinated varieties.

One of the frequently mentioned advantages of hybrid corn is its ability to stand up. Of course, hybrids vary in this characteristic; but most of the good ones possess it in a marked degree. A scene like the one presented in Fig. 15 was very rare before the days of hybrid corn. Fig. 16 shows the usual comparison between the better-standing hybrids and the open-pollinated varieties at the time of late harvest.

Summary of Four-, Three- and Two-Year Tests

Average results including two or more years' data are more dependable than those of a single year. The averages for all entries that have been grown for two years or longer, during the past four years in any section of the state have been computed. Table 3 summarizes these data by divisions of the state showing the differences between the average performance rating of the open-pollinated varieties and that of the individual entries. It should be pointed out that the entries in the 1934 tests were rated on the basis of total yield, sound yield, general quality, and percentage of erect plants. In 1935, 1936 and 1937 the entries were rated on the basis of sound yield (75 percent) and percentage of erect plants (25 percent).

In northeastern Illinois seven hybrids ranked 15 points above the standard open-pollinated varieties. In northern Illinois 19 hybrids exceeded the varieties by 15 points or more; north-central Illinois 20 hybrids so ranked; central Illinois, 26; south-central Illinois, 15; southern Illinois, 3; and south-eastern Illinois, 2.

Rate of Planting

The extensive use of hybrid corn has raised the question as to how thick this type of corn should be planted. Hybrid corn, it is argued. has a strong tendency to produce grain and a little crowding will not cause barrenness to as great a degree as with the average open-pollinated varieties. Such questions cannot be settled by discussion, so the Illinois Agricultural Experiment Station made some limited tests on the DeKalb Field in 1936 and again in 1937. The corn was planted at a rate of one kernel to the hill thicker than was desired and after the second cultivation the plots were thinned to the desired stand. Rates of 2, 3, 4 and 5 plants per hill were obtained. The rows were 40 inches apart each way. Plots were two rows wide and twenty hills long. Each rate of planting with each kind of corn was represented

TABLE 3.—Average difference between the performance rating of entries grown for four, three, and two years and the five open-pollinated varieties grown in the same fields the same seasons.

Northeastern Illinois

Rank.	Entry.	Difference in general performance rating in favor of the entry indicated[3].	Number of seasons included in the comparison.	Years in which tests were made.
1	*DeKalb Hybrid 421	32.8	2	1936,1937
2	*DeKalb Hybrid 404	28.6	2	1936,1937
3	*DeKalb Hybrid 203	27.9	3	1935–1937
4	*DeKalb Hybrid 433	25.0	2	1936,1937
5	°Funk Hybrid B31	21.9	2	1936,1937
6	*D Kalb Hybrid 493	18.1	3	1935–1937
7	Illinois Hybrid 316 (8-29xCC7) (Ax90)	15.9	2	1936,1937
8	Illinois Hybrid 318 (8-29xK) (Ax90)	13.4	2	1936,1937
9	*Gunn Western Plowman	5.0	3	1935–1937
10	Webb Will County Favorite	4.6	2	1935,1937
11	Huebsch Murdock Yellow Dent	—8.3	2	1936,1937

TABLE 3.—Continued

Northern Illinois

Rank.	Entry.	Difference in general performance rating in favor of the entry indicated[3].	Number of seasons included in the comparison.	Years in which tests were made.
1	*Illinois Hybrid 364 (Pfister)	32.7	2	1934,1936
2	*DeKalb Hybrid 404	28.3	2	1936,1937
3	*Illinois Hybrid 366 (Pfister)	24.2	4	1934–1937
4	*DeKalb Hybrid 421	22.9	2	1936,1937
5	*Illinois Hybrid 368 (Pfister)	20.8	4	1934–1937
6	*DeKalb Hybrid 433	20.6	2	1936,1937
7	*Iowa Hybrid 942 (I234xL289) (Os420xOs426)	18.7	2	1934,1936
8	*Illinois Hybrid 751 (Ax90) (WF9xHy)	18.3	3	1935–1937
9	*Pioneer Hi-Bred 335	18.3	2	1936,1937
10	*Pioneer Hi-Bred 315	18.0	2	1936,1937
11	*Illinois Hybrid 172 (R4xHy) (Ax540)	17.8	3	1934,1935,1937
12	*DeKalb Hybrid 493	17.5	3	1935–1937
13	*DeKalb Hybrid 497	17.1	2	1935,1936
14	*Pioneer Hi-Bred 311	16.7	3	1935–1937
15	*DeKalb Hybrid 203	16.1	4	1934–1937
16	*DeKalb Hybrid 435	16.0	2	1936,1937
17	*Iowa Hybrid 931 (Cl447xL289) (Os420xOs426)	15.9	2	1935,1936
18	*Illinois Hybrid 586 (4226x2204) (Hyx540)	15.3	3	1935–1937
19	*DeKalb Hybrid 492	15.0	3	1935–1937
20	*Funk Hybrid 214	14.8	3	1934–1936
21	*DeKalb Hybrid 419	13.3	3	1935–1937
22	*Funk Hybrid 215	12.3	2	1935,1936
23	*Pioneer Hi-Bred 323	11.6	4	1934–1937
24	Pioneer Hi-Bred 351	8.2	2	1934,1935
25	Illinois Hybrid 570 (Ax90) (Hyx540)	6.6	2	1935,1937
26	Webb Will County Favorite	1.7	4	1934–1937
27	Eckhardt Western Plowman	1.5	4	1934–1937
28	Simmons Will County Favorite	1.0	4	1934–1937
29	Gunn Western Plowman	—.6	4	1934–1937

North-Central Illinois

Rank.	Entry.	Difference in general performance rating in favor of the entry indicated[3].	Number of seasons included in the comparison.	Years in which tests were made.
1	*Moews Hybrid 10	25.8	2	1936,1937
2	*Funk Hybrid 212	25.4	2	1936,1937
3	*Illinois Hybrid 960 (R4xHy) (317x701)	24.1	3	1935–1937
3	*Illinois Hybrid 582 (R4x317) (Hyx540)	24.1	2	1936,1937
5	*Illinois Hybrid 546 (WF9xHy) (R4xTr)	23.3	3	1935–1937
5	*Illinois Hybrid 364 (Pfister)	23.3	2	1935,1936
5	*U. S. Hybrid 45 (Ind. 461-3xU.S.4-8) (Ill. HyxU.S.540)	23.3	2	1936,1937
8	*U. S. Hybrid 61 (Ill. R4xU.S.4-8) (Ill. Hy x U.S.540)	23.1	2	1936,1937
9	*Illinois Hybrid 366 (Pfister)	22.4	3	1935–1937
10	*Illinois Hybrid 360A (Pfister)	22.3	2	1935,1937
11	*U. S. Hybrid 44 (U.S. 187-2xU.S. 4-8) (Ill. HyxU.S.540)	22.1	3	1935–1937
12	*Iowa Hybrid 3110 (I159xI224A2) (L289xL317)	21.7	2	1935,1936
13	*Illinois Hybrid 360 (Pfister)	20.5	4	1934–1937
14	*Illinois Hybrid 751 (Ax90) (WF9xHy)	19.7	3	1935–1937
14	*Illinois Hybrid 368 (Pfister)	19.7	2	1934,1937
16	*Iowealth Hybrid 25	19.2	2	1936,1937
17	*Illinois Hybrid 936 (AxHy) (90x317)	18.2	3	1935–1937
18	*Illinois Hybrid 172 (R4xHy) (Ax540)	17.9	4	1934–1937
19	Illinois Hybrid 384 (WF9xR4) (AxHy)	16.2	3	1935–1937
20	*Pfister Hybrid 4857	15.9	4	1934–1937
21	*Funk Hybrid 206	14.7	2	1934,1935
22	Illinois Hybrid 570 (Ax90) (Hyx540)	14.2	3	1935–1937
23	*Illinois Hybrid 371 (AxL) (WF9xHy)	14.0	2	1935,1936
24	*Iowealth Hybrid C. I	13.4	2	1935,1936
25	*Iowa Hybrid 939 (I205xL289) (Os420xOs426)	12.6	3	1935–1937
26	*Iowealth Hybrid C	12.2	3	1935–1937
27	*Funk Hybrid 214	12.1	3	1934–1936
28	*Funk Hybrid 215	11.5	2	1935–1936
29	*Illinois-Iowealth Hybrid 25	11.3	2	1936,1937
30	*Pioneer Hi-Bred 311A	11.1	3	1935–1937
31	*Pfister Hybrid 584	10.7	2	1934,1935
31	°Pioneer Hi-Bred 308	10.7	2	1936,1937
33	*Iowa Hybrid 13 (L317xBl349) (Bl345xMc401)	10.6	2	1934,1935
34	°Hulting Yellow Dent	10.5	2	1934,1935
35	*Illinois Hybrid 372 (AxL) (WF9xR4)	9.2	2	1934,1935

TABLE 3.—Continued

Rank.	Entry.	Difference in general performance rating in favor of the entry indicated[3].	Number of seasons included in the comparison.	Years in which tests were made.
36	*Funk Hybrid 208	7.9	2	1934,1935
37	Funk Hybrid 220	6.2	3	1934–1936
38	Pioneer Hi-Bred 311	4.2	4	1934–1937
39	McKeighan Yellow Dent	3.9	4	1934–1937
40	Station Yellow Dent	3.8	3	1934,1936,1937
41	Morgan-Wallace Hybrid 106	2.8	4	1934–1937
42	Morgan-Wallace Hybrid 138	2.2	4	1934–1937
43	Iowa Hybrid 942 (I234xL289) (Os420xOs426)	1.7	2	1934,1935
44	Roeschley Yellow Dent	.4	3	1935–1937
45	Krug	—1.2	3	1934,1935,1937
46	Morgan-Wallace Hybrid 105	—2.4	2	1934,1935
47	Morgan-Wallace Hybrid 104	—3.8	2	1934,1935
48	Doubet Yellow Dent	—4.0	2	1934,1937
49	Queen of the Field	—6.7	2	1935,1936

Central Illinois

Rank.	Entry.	Difference in general performance rating in favor of the entry indicated[3].	Number of seasons included in the comparison.	Years in which tests were made.
1	*Illinois Hybrid 960 (R4xHy) (317x701)	29.7	3	1935–1937
2	*U. S. Hybrid 44 (U.S.187-2xU.S.4-8) (Ill.HyxU.S.540)	28.2	3	1935–1937
3	*Illinois Hybrid 582 (R4x317) (Hyx540)	25.5	2	1936,1937
4	*Moews Hybrid 10	25.4	2	1936,1937
5	*Funk Hybrid 212	25.2	2	1936,1937
6	*Illinois Hybrid 360A (Pfister)	23.9	3	1935–1937
7	*Funk Hybrid 244	23.8	2	1936,1937
8	*Illinois Hybrid 936 (AxHy) (90x317)	23.0	3	1935–1937
9	*Illinois Hybrid 754 (R4xHy) (90x317)	21.6	3	1935–1937
9	*U. S. Hybrid 61 (Ill.R4xU.S.4-8) (Ill. HyxU.S.540)	21.6	2	1936,1937
11	*Illinois Hybrid 546 (WF9xHy) (R4xTr)	21.5	3	1935–1937
12	*Iowealth Hybrid C	21.4	2	1936,1937
13	*Illinois Hybrid 360 (Pfister)	20.0	4	1934–1937
14	*Illinois Hybrid 753 (Sibley Estate)	18.8	3	1935–1937
15	Illinois Hybrid 384 (WF9xR4) (AxHy)	18.6	4	1934–1937
16	*Iowealth Hybrid 25	18.2	2	1936,1937
17	*Illinois Hybrid 710 (R4xHy) (Trx317)	17.8	3	1935–1937
18	*Illinois Hybrid 508 (HyxR4) (My)	17.6	2	1934,1935
19	*Illinois Hybrid 543 (90xHy) (R4xTr)	17.4	3	1935–1937
20	*Funk Hybrid 235	17.0	2	1936,1937
21	*Pioneer Hi-Bred 311A	16.3	3	1935–1937
22	*Illinois Hybrid 391 (AxHy) (Trx317)	16.0	4	1934–1937
23	*Funk Hybrid 207	15.7	2	1935,1936
24	*Pioneer Hi-Bred 311	15.6	3	1935–1937
24	*Illinois-Iowealth Hybrid 25	15.6	2	1936,1937
26	*Iowealth Hybrid C. A	15.3	2	1936,1937
27	*Illinois Hybrid 172 (R4xHy) (Ax540)	13.8	3	1934–1936
28	Pioneer Hi-Bred 305A	12.6	2	1936,1937
29	°Illinois Hybrid 372 (AxL) (WF9xR4)	11.3	2	1934,1935
30	Funk Hybrid 206	11.1	2	1934,1935
31	*Iowealth Hybrid CC	9.7	2	1936,1937
32	*Funk Hybrid 220	9.3	3	1934–1936
33	*Funk Hybrid 208	9.1	2	1934,1935
34	Pfister Hybrid 4857	8.7	3	1934,1935,1937
35	Funk Hybrid 220L	8.4	3	1935–1937
36	*Illinois Hybrid 368 (Pfister)	7.5	2	1934,1937
37	Pioneer Hi-Bred 308	7.4	2	1936,1937
38	*Pioneer Hi-Bred 306	7.1	2	1934,1935
39	Iowa Hybrid 13 (L317xBl349) (Bl345xMc401)	4.8	2	1934,1935
40	*Canterbury Yellow Dent	4.3	3	1934,1936,1937
41	Station Yellow Dent	3.6	4	1934–1937
42	McKeighan Yellow Dent	1.7	3	1934,1935,1937
43	Pfister Hybrid 584	1.3	2	1934,1935
44	Doubet Yellow Dent	— .5	4	1934–1937
45	Krug	—1.7	2	1934,1935
46	Mountjoy Utility Dent	—2.5	4	1934–1937
47	Sommer Yellow Dent	—5.1	3	1934–1936
48	Stiegelmeier Yellow Dent	—5.5	2	1934,1935
49	Herndon Yellow Dent	—6.9	2	1935,1936

TABLE 3.—Concluded

South-Central Illinois

Rank.	Entry.	Difference in general performance rating in favor of the entry indicated[3].	Number of seasons included in the comparison.	Years in which tests were made.
1	*Illinois Hybrid 960 (R4xHy) (317x701)	36.1	3	1935–1937
2	Iowa Hybrid 13 (L317xBl349) (Bl345xMc401)	36.0	2	1934,1936
3	°Funk Hybrid 244	30.5	2	1936,1937
4	*Illinois Hybrid 945 (Trx317) (WF9xR4)	28.0	2	1935,1936
5	*Funk Hybrid 207	26.2	4	1934–1937
6	*Illinois Hybrid 582 (R4x317) (Hyx540)	26.1	2	1936,1937
7	*Illinois Hybrid 46 (4226x5675) (R4xHy)	25.4	2	1936,1937
8	Illinois Hybrid 947 (R4xPr) (Trx317)	25.0	3	1935–1937
9	°Illinois Hybrid 710 (R4xHy) (Trx317)	21.1	3	1935–1937
10	°Funk Hybrid 235	20.0	2	1936,1937
11	Illinois Hybrid 538 (5120x4211) (R4xTr)	17.2	3	1935–1937
12	*Illinois Hybrid 54 (5120x4211) (R4xHy)	16.8	2	1935,1936
13	Funk Hybrid 220L	16.6	3	1935–1937
14	*Illinois Hybrid 508 (HyxR4) (My)	15.9	2	1934,1935
15	*Iowealth Hybrid CC	15.6	2	1935,1937
16	Canterbury Yellow Dent	2.7	3	1934–1936
17	Station Yellow Dent	1.3	4	1934–1937
18	Rice White Dent	.5	3	1935–1937
19	Bunning White Dent	.2	2	1936,1937
20	Wilson Yellow Dent	.1	2	1935,1937
21	Waddell Utility Yellow Dent	—1.1	2	1935,1937
22	Shuman Golden Beauty	—4.3	3	1935–1937
23	Eversole White Dent	—6.0	4	1934–1937
	Southern Illinois			
1	*Funk Hybrid B50	48.6	2	1936,1937
2	Illinois Hybrid 28 (R4xHy) (NI4xSG)	36.8	2	1936,1937
3	Illinois Hybrid 66 (5678x5120) (R4x317)	19.5	2	1936,1937
4	St. Charles White	7.2	4	1934–1937
5	Moore Yellow Dent	— 1.8	4	1934–1937
5	Waddell Golden Beauty	— 1.8	3	1934–1936
7	Champion White Pearl	— 6.2	4	1934–1937
8	Blackhawk	— 7.1	4	1934–1937
9	Station Yellow Dent	— 8.8	4	1934–1937
10	Pride of Saline	—15.6	3	1934–1936
11	Waddell Utility White Dent	—19.5	3	1934,1935,1937
12	Helms Yellow Dent	—21.3	2	1936,1937
	Southeastern Illinois			
1	*Illinois Hybrid 960 (R4xHy) (317x701)	23.7	2	1936,1937
2	*Illinois Hybrid 940 (5120x4211) (I159x317)	20.0	2	1935,1937
3	*Illinois Hybrid 947 (R4xPr) (Trx317)	12.8	3	1935–1937
4	Funk Hybrid 235	9.8	2	1936,1937
5	Wilson Yellow Dent	1.6	3	1935–1937
6	Helms Yellow Dent	.4	2	1936,1937
7	Illinois Hybrid 54 (5120x4211) (R4xHy)	.3	2	1935,1936
8	Eversole White Dent	— .2	2	1935,1936
8	Pride of Saline	— .2	2	1935,1936
10	St. Charles White	—1.8	2	1935,1937
11	Leaming	—3.2	2	1936,1937
12	Moore Yellow Dent	—5.5	2	1935,1936
13	Waddell Golden Beauty	—6.2	2	1935,1936

*Those entries marked with an asterisk equaled or exceeded the average of the five open-pollinated varieties in both yield of sound corn and percent of erect plants during all years included in the comparison.

° Entries marked with a circle were exceeded by the average of the five open-pollinated varieties in lodging resistance only and that occurred in only one year.

[3] Entries in the 1934 tests were rated on the basis of total yield, sound yield, general quality, and percentage of erect plants. In 1935, 1936 and 1937 the entries were rated on the basis of sound yield, 75 percent, and proportion of erect plants, 25 percent.

by nine plots, the results of which were averaged. The data on yield of grain per acre for 1936 are presented in Table 4, and for 1937 in Table 5. The entries are grouped according to their yield response to increased thickness of planting. Those that yielded best at four stalks per hill are in group one and those that yielded best at three stalks are in group two. From this it would seem that the statement cannot be made unreservedly that hybrids will profitably bear thicker planting than open-pollinated varieties. More nearly correct would be the statement that some hybrids have the capacity to give their maximum yields when planted at a thicker rate than is commonly recommended for open-pollinated varieties. In other words, information as to optimum planting rate will need to be obtained for each hybrid.

Table 6 contains data on the influence of rate of planting on certain characteristics of the crop. All the hybrids and open-pollinated varieties in the tests have been averaged in compiling these results. It will be noted that on the average the highest yield was obtained at the four kernel per hill planting rate. The test weight per bushel declined slightly as the thickness of planting increased. The percentage of barren plants increased sharply as the planting rate increased. On the other hand, the size of the ears, the weight of 1,000 kernels,

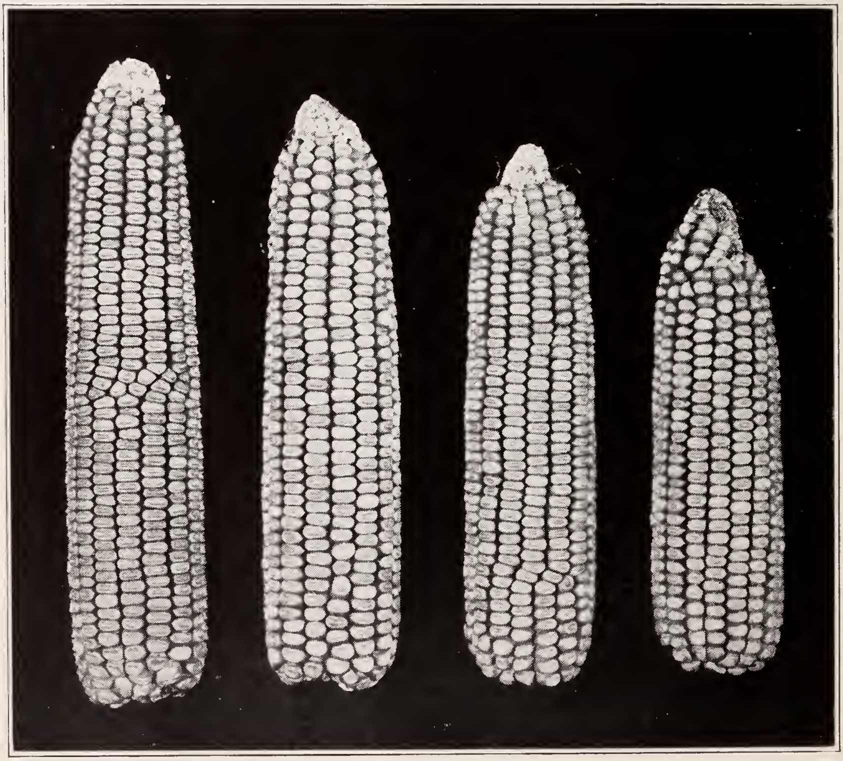


Fig. 17. Average ears of corn produced by plants growing 2, 3, 4 and 5 to the hill on the DeKalb Field, 1937. They weighed .56, .50, .43 and .38 pounds, respectively.

TABLE 4.—Response of Corn Varieties and Hybrids on the DeKalb Field in 1936 to Thickness of Planting.

Kind of Corn.	Yield of Sound Corn per acre with the indicated number of plants per hill.			
	2	3	4	5
Group 1	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*
Illinois Hybrid 366 (Lazier)	55.0	61.6	64.7	65.9
Iowealth Hybrid A	42.3	49.8	59.2	50.3
Illinois Hybrid 368 (Lazier)	53.2	59.6	60.7	61.1
Funk Hybrid 215	61.3	71.9	78.7	76.2
DeKalb Hybrid 203	58.5	70.2	74.8	73.5
Illinois-Iowealth Hybrid 20	55.1	69.7	71.2	65.6
DeKalb Hybrid 493	47.4	49.9	50.5	47.7
Average	53.3	61.8	65.7	62.9
Percent of average yield at two stalks	100.0	115.9	123.3	118.0
Group 2				
Pioneer Hi-Bred 323	60.8	73.8	67.6	69.3
DeKalb Hybrid 404	65.0	71.8	70.9	66.2
Pioneer Hi-Bred 311	50.5	55.2	53.7	53.8
Pioneer Hi-Bred 315	73.3	74.1	72.8	73.9
DeKalb Hybrid 55	59.1	60.1	59.0	50.6
DeKalb Hybrid 108	57.3	60.3	55.6	49.6
Average	61.0	65.9	63.3	60.6
Percent of average yield at two stalks	100.0	108.0	103.8	99.3
Group 3—Open-pollinated varieties				
Griffith Early Dent	40.5	44.4	49.1	39.1
Gunn Western Plowman	42.9	43.4	44.5	42.9
Eckhardt Western Plowman	55.2	56.8	54.9	57.3
Average	46.2	48.2	49.5	46.4
Percent of average yield at two stalks	100.0	104.3	107.1	100.4

TABLE 5.—Yield Response of Corn Varieties and Hybrids on the DeKalb Field in 1937 to Thickness of Planting.

Kind of Corn.	Yield of Sound Corn per acre with the indicated number of plants per hill.			
	2	3	4	5
Group 1	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*
DeKalb Hybrid 203	71.0	83.8	90.4	90.1
Illinois Hybrid 189	68.1	78.0	81.6	74.4
Illinois Hybrid 1082	67.9	75.6	79.9	77.8
Illinois Hybrid 400	63.6	74.0	81.0	78.5
Illinois Hybrid 172	52.2	79.9	79.9	77.5
Wisconsin Hybrid 650	56.7	59.6	69.0	68.5
Illinois Hybrid 570	60.3	62.7	63.9	62.9
Illinois Hybrid 179	54.9	59.9	64.7	63.4
Average	61.8	71.7	76.3	74.1
Percent of average yield at two stalks	100.0	116.0	123.5	119.9
Group 2				
DeKalb Hybrid 404	76.8	93.2	87.3	82.6
Simmons Will County Favorite	61.2	71.6	70.9	68.0
Illinois Hybrid 751	67.8	69.2	63.5	49.0
Gunn Western Plowman	55.9	66.5	63.4	61.9
Average	65.5	75.2	71.3	65.4
Percent of average yield at two stalks	100.0	114.8	108.9	99.8

TABLE 6.—Influence of Thickness of Stand upon the Character of the Crop Produced at DeKalb.

1936

Character.	Data secured when planted at the following rates per hill in rows 40 inches apart each way.			
	2	3	4	5
Yield per acre (bushels)	54.8	60.8	61.7	58.9
Test weight per bushel (pounds)	55.0	54.5	54.3	54.2
Percent of barren plants (percent)	1.2	9.3	15.7	23.6
Weight of 1,000 kernels (grams)	264.7	256.7	247.5	236.3
Weight of ears (water-free shelled corn, pounds)	.32	.26	.22	.18
1937				
Yield per acre (bushels)	65.0	72.8	74.6	71.2
Test weight per bushel (pounds)	56.8	56.8	55.9	55.8
Percent of damaged corn (percent)	.31	.28	.89	.91
Weight of 1,000 kernels (grams)	271.5	252.7	240.8	224.9
Number of ears per stalk	1.01	.91	.83	.81
Field weight of ears (pounds)	.56	.50	.43	.38
Erect plants at harvest (percent)	78.0	69.1	60.8	53.5
Moisture in grain at harvest (percent)	19.3	20.2	20.8	21.2

the average number of ears per stalk, and the percentage of plants erect at harvest declined at the thicker rates of planting. Fig. 17 shows an average size ear produced on stalks growing 2, 3, 4 and 5 respectively, to the hill.

Thick planting tended to delay maturity of the plants as indicated by the slightly higher moisture content of the shelled corn from the higher rates of planting.

Reaction to Insects

Resistance to the attack of certain insects is one of the desirable characteristics of some corn hybrids. The next few pages give a brief summary of information which is now available regarding some of the hybrids that are on the market.

Insect resistance in corn may take the form of avoidance of certain strains by the insect, tolerance of strains to the attack, or recovery following the attack. Any of these evidences of resistance may be due to some as yet unknown physiological or morphological characteristics. The lack of these characteristics may, on the other hand, be responsible for the fact that many hybrids have been shown to be distinctly susceptible to insect attack.

Since 1932 the cooperating agencies have been attempting to determine the resistance and susceptibility of corn hybrids to the attack of several insects. The following represents a summary of information obtained to date and attempts to indicate the inbred lines contributing any resistance which may be indicated. Probably the outstanding point demonstrated is that there is a great deal of variation in the response of hybrids. Some of those shown to be susceptible to attack are no more resistant than commonly used open-pollinated varieties, while others are far more resistant.

It is impossible to make a complete inventory of all hybrids, but the available information indicates that it behooves each farmer planning to grow a corn hybrid to determine whether it is resistant to the insects to which it is most likely to be exposed on his farm during the season when it will be used.

Chinch Bugs

The general outbreak of chinch bugs, *Blissus leucopterus* Say, in 1933 and 1934 provided a demonstration of the resistance or susceptibility of certain corn hybrids to the attack of second brood chinch bugs. The results of strip test plantings in farmers' fields have been previously published.[4] The general summary of the results is reproduced in Table 7.

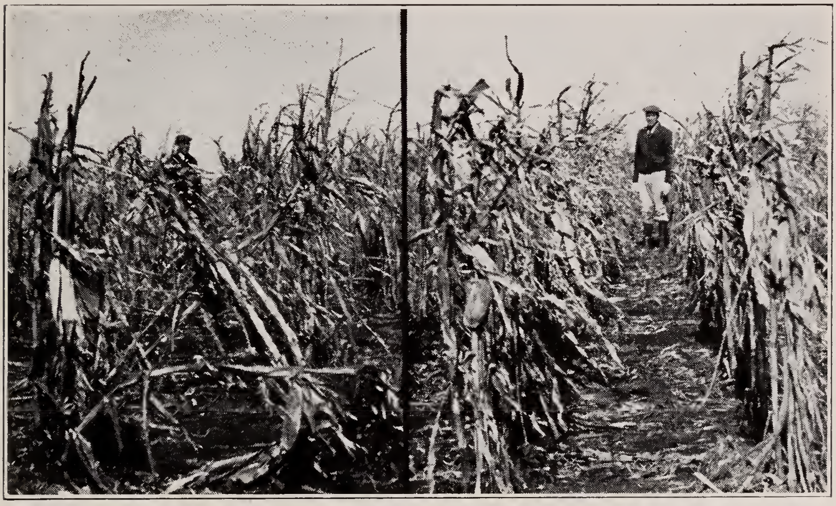


Fig. 18. Comparative condition of a resistant (right) and susceptible (left) hybrid growing in close proximity under a severe attack by second-brood chinch bugs. Franklin, Illinois, 1936.

Two of the 1936 Corn Performance Test Fields were heavily infested with chinch bugs. At the Franklin (Morgan County) field a fairly general infestation of bugs was present. The field also suffered severely from drouth and grasshoppers. In a portion of the field where uniform chinch bug conditions prevailed certain varieties and hybrids demonstrated their resistance or susceptibility, and the results are shown in Table 8 and Fig. 18.

At the Sullivan field in Moultrie county a portion of the field was heavily infested while the remainder of the field had very light or no infestation. The effect of chinch bugs on two hybrids grown in the same field under such conditions is shown in Table 9.

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[4] J. R. Holbert, W. P. Flint, J. H. Bigger, and G. H. Dungan, Resistance and Susceptibility of Corn Strains to Second Brood Chinch Bugs, Iowa State College Journal of Science, Vol. IX, No. 3, 1935, pp. 413-425.

Up to now the following hybrids had shown themselves to be relatively resistance to the attack of second brood chinch bugs: Illinois Hybrids 7, 46, 126, 172, 221, 582, 710, 827, 863, 947, 960. Indiana Hybrid 829, and Missouri Hybrid 11. Study of basic material has indicated that such resistance may be traceable to the presence of inbreds Hy, 90, 5120, 38-11, Pr, K4, WF9, R4, in the constitution of the above hybrids. Further studies may disclose other inbreds which contribute to resistance.

Information obtained during 1937 also indicated that the limits of maximum adaptation of a hybrid may involve its response to insects. For example, Illinois Hybrids 960, 582 and 710 were grown extensively in the southern part of the State. While their general performance

TABLE 7.—Summarized Data From 20 Cooperative Field Tests in 8 Central Illinois Counties Comparing the Local, Open-Pollinated Varieties and Hybrids Differing in Chinch Bug Resistance, all Fields Heavily Infested With Second Brood Chinch Bugs, 1934.

Kind of Corn.	Percentage of plants standing.	Acre Yield. Total.	Acre Yield. Sound (not conspicuously damaged by bugs or ear rots).
	Percent.	*Bushels.*	*Bushels.*
22 Local varieties	46.9	35.4	22.8
13 Chinch bug susceptible hybrids	42.1	27.3	13.3
16 Hybrids intermediate in resistance	58.6	39.7	26.9
10 Chinch bug resistant hybrids	65.2	46.3	35.4

TABLE 8.—Percentage of Plants Erect at Harvest and Sound Yield of Various Strains of Corn Grown Under Heavy Second-Brood Chinch Bug Attack, With Some Grasshopper Damage, on the Corn Performance Test Field at Franklin, Illinois, 1936.

Strain of Corn.	Plants erect at harvest.	Acre yield of Sound Corn.
	Percent.	*Bushels.*
3 Open-pollinated varieties	56.7	8.1
1 Chinch-bug-susceptible hybrid	70.0	2.9
2 Hybrids intermediate in resistance	82.5	19.8
3 Chinch-bug-resistant hybrids	90.0	33.9

TABLE 9.—Comparison of Two Hybrids, Each Growing Under Very Light and Under Very Heavy Second-Brood Chinch Bug Infestation in the Same Field in Moultrie County, Illinois, 1936.

Strain of Corn.	Percent plants erect at harvest.		Reduction due to second-brood chinch bugs.	
	Under light infestation.	Under heavy infestation.	Erect plants.	Yield.
	Percent.	*Percent.*	*Percent.*	*Percent.*
A rather susceptible hybrid	50.0	30.0	40.0	27.3
A resistant hybrid	90.0	80.0	11.1	6.0

was very satisfactory, they did not exhibit the chinch bug resistance indicated when they were grown in the central and north-central portions of the State.

Intense infestations of chinch bugs developed on the performance test fields at Edgewood and Alhambra during 1937.[5] A careful study of the hybrids grown on the fields indicated that Illinois Hybrids 863, 450, 447, 1010 and some others as well as some commercial hybrids, were resistant to second-brood chinch bug attack.

Southern Corn Rootworm

Seasonal conditions in Illinois during 1935 were favorable to the southern corn rootworm, *Diabrotica duodecimpuncatata* Fab., and the insect was abundant in the entire central, south-central, and southern sections of the State where corn performance tests were located. The lodging which occurred on these fields was largely due to early and mid-season feeding by this insect. The "per cent erect" figures in the tables for these sections in the 1936 report of the tests[6] are a good index of the resistance of the strain to rootworm attack. This resistance to lodging following rootworm injury appears to be at least partially due to recovery of root system.

Information with regard to rootworm resistance was obtained from the corn performance test fields during 1937.[7] A column labeled "mid-season lodging due to rootworm" in Tables 4, 5, and 8 in the report for that year gives rootworm response of the hybrids included in the tests. The information is summarized in Table 10 for the five best hybrids and the five poorest hybrids in that respect, and the five open-pollinated varieties included in the tests, and emphasizes the importance of knowing the rootworm resistance of the hybrid corn that is being grown (Fig. 19).

TABLE 10—Mid-Season Lodging of Corn Varieties and Hybrids, on Five Corn Performance Test Fields, Due to Attack of the Southern Corn Rootworm, 1937.

Location.	Average 5 best hybrids on field.		Average 5 poorest hybrids on field.		Average all open-pollinated varieties on field.	
	Lodged plants.	Acre yield.	Lodged plants.	Acre yield.	Lodged.	Average acre yield.
	Percent.	*Bushels.*	*Percent.*	*Bushels.*	*Percent.*	*Bushels.*
Cambridge	38.6	121.3	87.3	110.9	87.9	104.0
Adair	28.3	102.7	78.1	97.8	82.1	92.7
Stanford	9.0	103.7	59.0	99.9	50.3	99.9
Brocton (Exc. Kans. Hybs.)	34.5	75.0	63.1	79.5	73.4	72.1
Albion	20.7	87.2	65.9	83.6	78.8	79.4

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[5] Illinois Corn Performance Tests, 1937. Bul. 440, Illinois Agricultural Experiment Station, January 1938, G. H. Dungan, R. O. Snelling, W. J. Mumm, J. H. Bigger, A. L. Lang.

[6] G. H. Dungan, J. R. Holbert, W. J. Mumm, J. H. Bigger, and A. L. Lang, Illinois Corn Performance Tests, Results for 1935. Illinois Bulletin 427, December 1936.

[7] Illinois Agricultural Experiment Station, Bulletin 440.

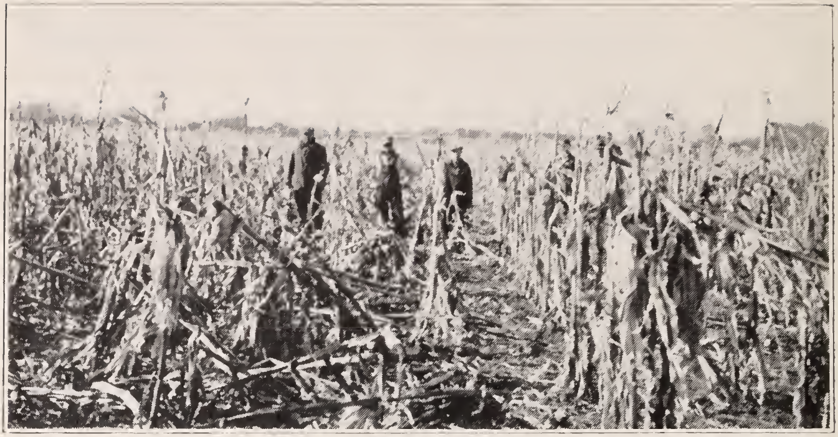

Fig. 19. Comparative effect of a severe attack by the southern corn rootworm on a locally adapted open-pollinated variety (left) and a rootworm-resistant hybrid (right) in field tests at Normal, Illinois, 1935.

Grasshoppers

During 1936 a widespread grasshopper, Locustidae, outbreak gave opportunity for some observations on the response of hybrids to grasshopper attack. It was clearly demonstrated that some strains are far more attractive to these pests than other strains where the two were grown in close proximity in the same field. One of the best cases of this sort appeared in a strip test in Warren County (Fig. 20).

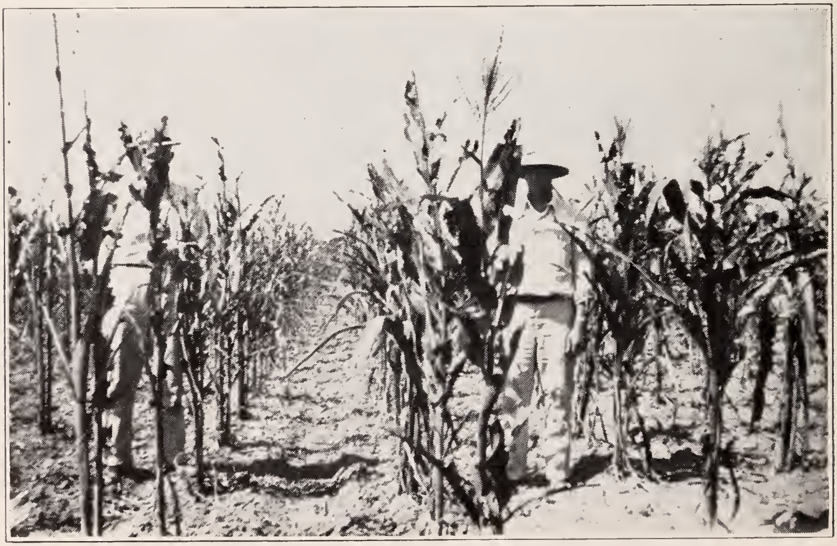

Fig. 20. Showing the differential feeding of grasshoppers on two hybrids growing in adjacent plots on a farm in Hancock County, Illinois, 1936.

Table 11 shows the result of an obesrvation in a field where two hybrids were grown in four-row plots the length of the field in which grasshopper damage was very severe at one end, but no appreciable damage occurred in the remainder of the field.

The following hybrids were injured less than average by grasshoppers during 1936: Illinois Hybrids 391, 960, 582, 710, 311, 126, 161, 936 and 947. Results with these hybrids indicate that inbreds L317, 38-11, and Pr may carry factors contributing to this unattractiveness.

TABLE 11.—Effect of Heavy Feeding by Grasshoppers on Two Corn Hybrids Grown in a Field Near Monmouth, Warren County, Illinois, 1936. Grasshoppers Invaded One End of the Plots From Adjacent Clover Field but Left the Other End Undamaged.

Strain of Corn.	Total acre yield of corn on plots.		Acre yield of sound corn on plots.		Percent of sound corn on plots.	
	Undamaged part of field.	Damaged part of field.	Undamaged part of field.	Damaged part of field.	Undamaged part of field.	Damaged part of field.
	Bushels.	*Bushels.*	*Bushels.*	*Bushels.*	*Percent.*	*Percent.*
A susceptible hybrid	44.9	26.4	42.5	17.9	94.7	67.8
A resistant hybrid	63.8	49.0	63.1	47.7	98.9	97.3

White Grubs

During 1936 a small field in which double-cross hybrids were being produced was located on land infested with white grubs, *Phyllophaga* spp. Great differences in the ability to resist this attack by the hybrids being used was clearly apparent to the most casual observer. Table 12 lists the single crosses present in the field and the per cent of erect plants compared with the pollen parent Tr x L317 which was susceptible to lodging under these circumstances. The lodging was determined by digging and root examinations as being due to white grub injury.

TABLE 12.—Differential Response of Certain Single-Cross Hybrids to the Attack of White Grubs in Crossing Plot at Muncie, Illinois, September 25, 1936.

Cross.	Number stalks examined.	Percent stalks erect.	Percent increase in plants erect over average of Trx 317.
5120xR4	262	80.2	403.0
Trx317	118	28.8	
90x4211	142	94.4	474.4
5120x4211	264	67.4	338.7
Trx317	115	24.3	
2204xHy	266	65.0	326.6
Trx317	121	15.7	
4-8xHy	138	82.6	415.1
Trx317	118	13.6	
4211xHy	136	92.6	465.3
HyxWF9	206	83.0	417.1
Trx317	121	17.4	
R4xHy	264	83.3	418.6
Total of 5 replicates of Trx317	593	19.9	

Corn Earworms

Studies of corn in test plots near Bloomington during the fall of 1934 demonstrated a great variation in attractiveness of the strains to the corn earworm, *Heliothis obsoleta* Fab. Varieties and hybrids growing in adjacent rows showed comparative ear infestations of 48 per cent and 100 per cent or comparative kernel infestations of 2.7 per cent and 9.7 per cent for the resistant and susceptible strains, respectively. This problem is now being further studied in cooperation with the Bureau of Entomology and Plant Quarantine of the United States Department of Agriculture. Work to date, which has been verified by Mr. E. V. Walter of the Bureau, indicates that the inbreds 90, Hy, R4, and Pr transmit factors for resistance to this insect. Since 1936 this part of the project has been carried on by Mr. R. A. Blanchard of the Bureau of Entomology and Plant Quarantine.

DRYING AND STORING SEED CORN

Another problem which has come with the development of hybrid corn is how best to cure and store the seed. Because of the necessity of curing large quantities of seed corn in a relatively short time most producers of hybrid corn use the system of drying known as the "bin method." Heated air is forced through the ear corn in a bin until the moisture content of the grain has been reduced to about 13 per cent. In some cases the corn is dried only partially in the ear. The ears are then shelled and the shelled corn further dried to the desired moisture content by allowing it to fall down a vertical shaft up through which flows a stream of warm air. The highest safe temperature for seed corn drying is 110° F. The time usually required to dry a batch of corn in a bin is from 72 to 120 hours.

Perhaps the most nearly ideal way to cure seed corn is to use hangers which provide a free circulation of air around each ear. After drying the corn should be stored in a room which can be heated to prevent freezing on the coldest days of winter. Drying on hangers is not enough as the experience of many farmers in 1935 will attest. Storage in a room which can be heated to prevent the absorption of water from the atmosphere and the condensation of moisture on the ears is essential.

An experiment was conducted in 1937 to get some data on the relative seed value of corn cured in bins and that cured on hangers. In October, 1936, corn was collected from six different drying plants. Twenty ears were taken of each kind of corn as it went into the bin. This corn was taken to the Agronomy Building on the South Farm of the University of Illinois and placed on Martin hangers where it remained until April. Heat was supplied to the room where the corn was stored to hold the temperature somewhat above freezing at all times. In the spring the tip, butt, and other irregular kernels were removed and the remainder of the ears shelled and treated with ethyl mercury phosphate, preparatory to planting. A similar sample of the same kind of corn that had been dried in a bin was obtained from the individuals and organizations cooperating in the experiment. This corn came shelled, graded, and treated ready for planting, having been handled in the same way as regular commercial seed. These two lots of corn were paired and planted on the Agronomy South Farm in 1937, to make a field test of their growth and yield performance. Ten replications of 20 hills each were planted on May 15. The average results in respect to field stand and yield per acre are presented in Table 13.

In four of the six cases the yield of corn grown from seed dried on hangers exceeded that of seed dried in a bin. The average superiority of the seed dried on hangers over that dried in bins was 2.6 bushels per acre, or 2.9 per cent. In respect to field stand, the hanger-dried seed exceeded the bin-dried corn by 1.3 per cent.

TABLE 13.—Results of Tests With Corn Varieties and Hybrids Dried on Hangers and in Bins Through Which Heated Air Was Forced. Urbana, 1937.

Drying Plant.	Yield per acre produced by seed dried.		Field stand of plants produced by seed dried.	
	On hanger.	In bin at 110° F.	On hanger.	In bin at 110° F.
	Bushels.	*Bushels.*	*Percent.*	*Percent.*
Number 1	95.3	89.0	96.2	93.5
Number 2	100.8	101.1	95.7	93.4
Number 3	93.9	88.1	94.3	97.0
Number 4	93.9	91.1	95.8	95.3
Number 5	73.2	72.0	93.3	91.8
Number 6	91.4	91.6	96.3	93.0
Average	91.4	88.8	95.3	94.0

These small differences are insignificant and well within the experimental error. One of the factors of difference which may be responsible for the results of the two kinds of seed not being nearer the same is the thoroughness with which the seed was graded. In the case of the hanger-dried corn all the seed coat injured kernels and all mis-shapen and small grains were carefully picked out of each ear by hand before the corn was shelled. Where a large part of the work of shelling and grading was done by machinery as in the case of the bin-cured corn, there was perhaps a few more injured kernels left in the good seed grade.

The use of the bin drier makes possible the handling of a seed crop in an immature condition before an untimely killing frost ruins it. Since the bin drier, therefore, preserves high seed quality in those exceptional seasons when other methods fail, and since it gives essentially as good seed in other years when no emergency exists, it would appear that the bin drier is a safe and desirable method to use regularly with all seed corn.

SOIL ADAPTATION OF CORN HYBRIDS

The inherent high yielding capacity of hybrid corn is not expressed to the fullest extent on soils relatively low in productivity. Comparisons among hybrids and open-pollinated varieties on soils varying in productivity and under different systems of soil management indicate that the better hybrids are more responsive to good soil and good soil management practices and more sensitive to poor soil and poor soil management practices than most of the commonly grown open-pollinated varieties of corn. Hybrid corn emphasizes more than ever the importance of maintaining soils in a high state of fertility.

Productivity-Level Tests

For the past three years some of the better corn hybrids have been tested along with open-pollinated corn on soils varying in productivity at Sibley, Ill., on the Sibley estate and at Urbana, on the Agronomy South Farm. At each location areas have been used which represented a low and a high level of productivity. In yields of sound corn the high levels at Sibley and at Urbana have averaged about equal for the period of the test. The low level at Urbana has been intermediate between the low level at Sibley and the two high levels. In the discussion that follows only the data from the high and low levels at Sibley will be used, as they represent the two extremes and present a clear

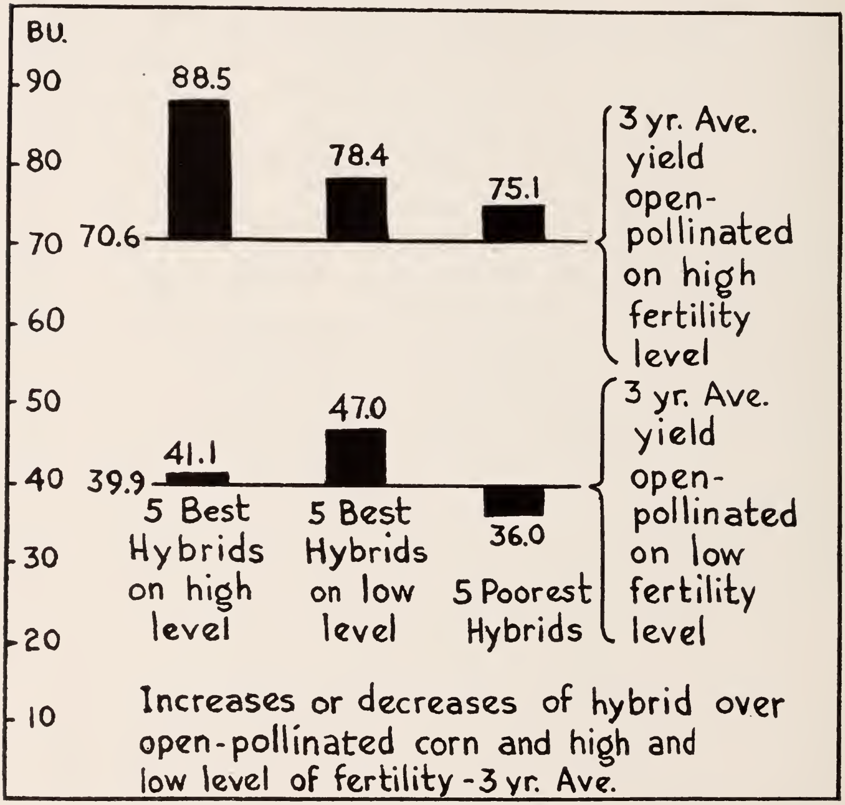

Chart I. The five hybrids that were best in sound yield on the more fertile soil were 17.5 bushels better than the open-pollinated variety on the high level, but only 1.2 bushels better on the low level. Those that were best on the low level were not any more responsive to a high level of fertility. The poorest hybrids were 4.5 bushels above the open-pollinated varieties on good soil but 3.3 bushels below the open pollinated on the poor soil.

picture of the principles involved. Open-pollinated corn averaged, for the test, 49 bushels an acre annually on the low level at Sibley. Two of the three years were exceedingly favorable for corn.

In order to show the relation of hybrids to soil productivity, comparisons have been made among the yields of sound corn (Chart I). The five highest yielding hybrids on the more productive area were 17.5 bushels an acre above the open-pollinated check variety. The same five high yielding strains were only 1.2 bushels better than the open-pollinated variety on the low level of fertility. There were five strains which produced 7.1 bushels more corn on the low level than the check,

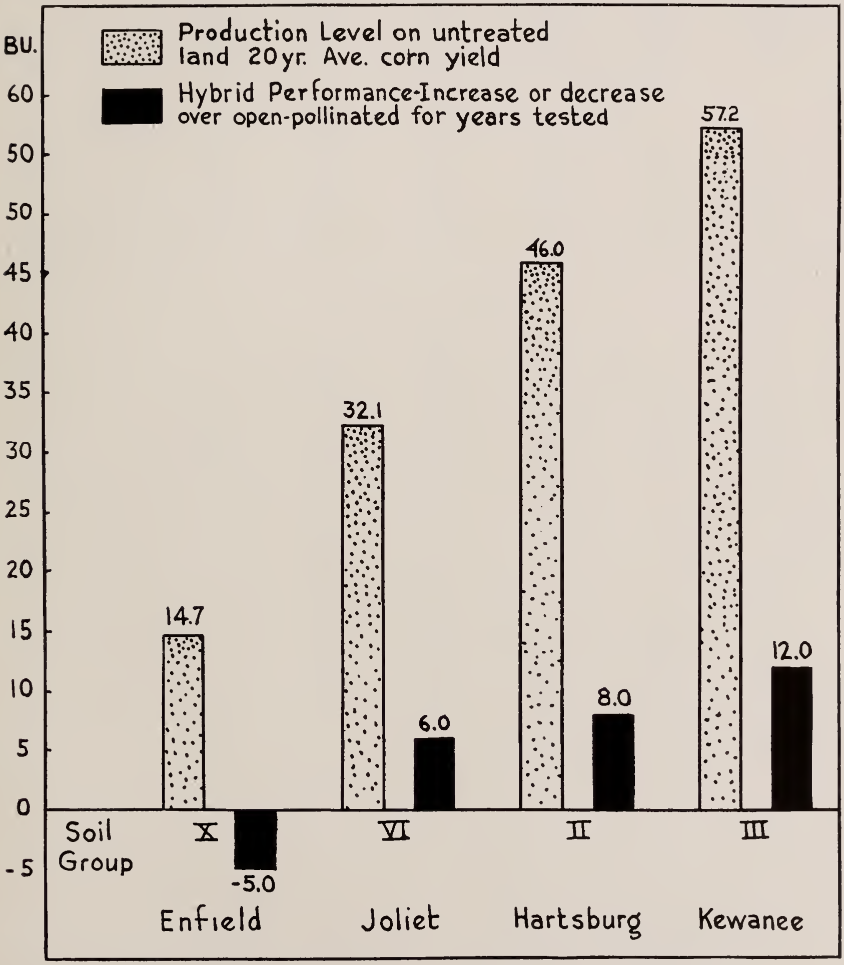

Chart II. RELATION OF SOIL TO HYBRID CORN PERFORMANCE.

Group X	Yellowish gray soil with impervious, non-calcareous subsoils.
Group VI	Dark soils with heavy impervious calcareous subsoil.
Group II	Dark soils with heavy calcareous subsoil.
Group III	Dark soils with non-calcareous subsoil.

but these five were not any more responsive to a greater supply of plant food as they were only 7.8 bushels better on the highly productive soil.

Even the five poorest hybrid strains were 4.5 bushels better than the open-pollinated variety on the fertile soil but on the unfertile soil they averaged 3.3 bushels below the open-pollinated check.

Good high yielding hybrids that were responsive to a high level of fertility seemed to be very sensitive to a lack of that fertility. In general, all hybrid strains were markedly superior to the open-pollinated variety when grown on good soil. However, when grown on soil relatively low in fertility they were not greatly superior in yield of sound corn and there were cases in which they were considerably inferior to the adapted open-pollinated corn.

Influence of Soil and Soil Management Practices

Recent development in hybrid corn production has necessitated the comparing of various hybrids and open-pollinated varieties of corn on the outlying soil experimental fields for the purpose of determining those most useful for indicating the value of soil management practices. These tests have brought to light some interesting and valuable relationships that exist among the various strains of corn when grown in different soil environments.

Yield Response

Yield is the first consideration in corn production. It is influenced directly or indirectly by such factors as lodging, quality, stalk barrenness, resistance to insects, diseases, cold, heat, and drouth. Many of these factors have been taken into consideration in the breeding and production of the better hybrids that have been used in these tests. Superiority in yield reflects how successful the process has been and also reflects how closely related these factors are to fertility in soils. The influence of some of these factors has been studied independently and will be discussed later. The yields, however, tell the important story.

Yield performance of hybrids has been compared with that of open-pollinated corn on the untreated land of four major soil groups of the State which differ widely in their physical structure and in their production capacity for corn (Chart II). For these same groups yield performances have been compared where various systems of soil treatment were used (Chart III).

Results similar to those of the productivity-level tests were obtained on the various soil groups of the soil experiment fields. The superiority of the hybrids over the open-pollinated varieties becomes more pronounced as the natural productivity of the soil increases. Likewise the same relation holds true for systems of soil treatment. Hybrids showed their greatest superiority on those treatments which were most effective in raising the general productivity of the soil. At Enfield, in soil group No. 10, on relatively unproductive, light-colored soil, the hybrid was not so good as the standard variety on untreated land. With manure and limestone, or with sweet clover, residues, limestone, phosphate, and potash, the hybrid was, respectively, 17 and 12 bushels better (an acre) than the variety. Response on the Joliet field in Will County on an

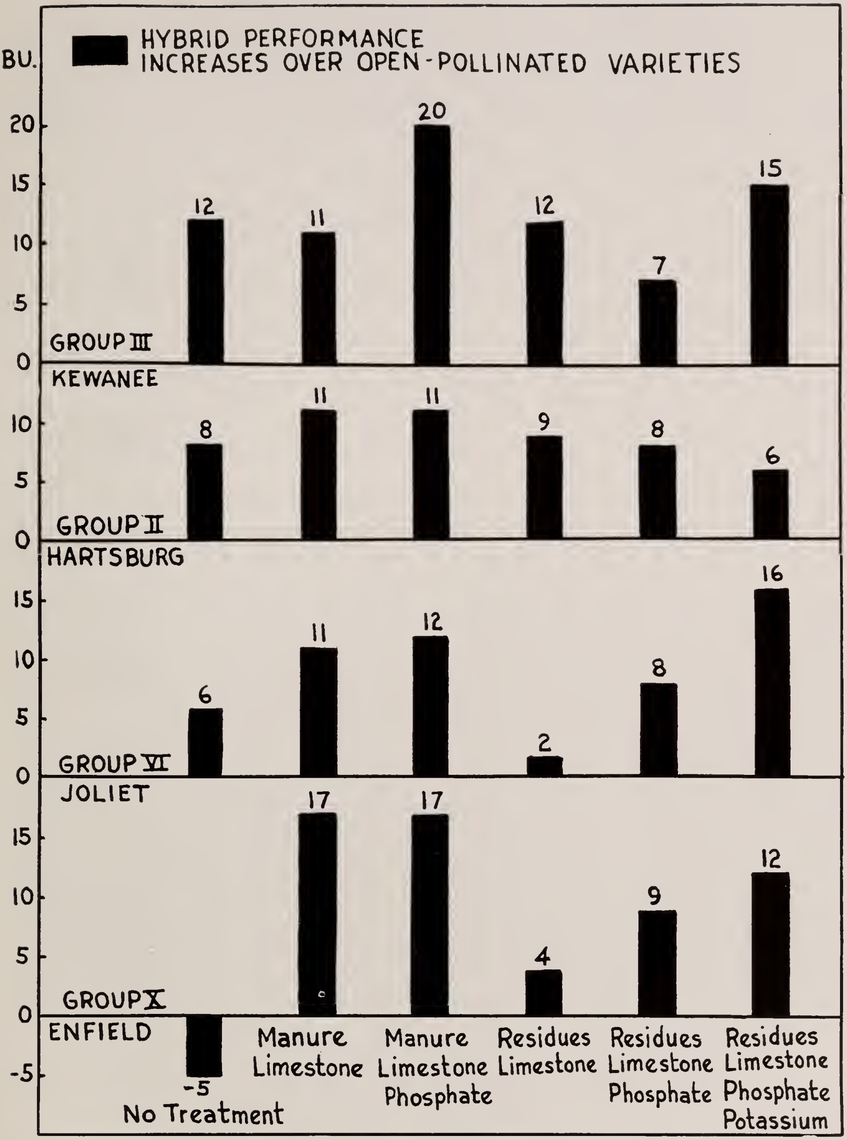

Chart III. RELATION OF SOIL TREATMENT TO HYBRID CORN PERFORMANCE.

In yield hybrid corn superiority over open-pollinated varieties is directly related to the natural productivity of the soil and to the influence of soil management practices on the soil.

unproductive, dark-colored soil was not greatly different from that at Enfield, on the treated plots. The relatively highly productive, dark-colored soil of the Hartsburg field is a soil which has not shown any crop response for soil treatment other than for organic matter. Correlative with this reaction hybrids have not been outstandingly superior on any of the treatments on this field. Just the reverse was true at the Kewanee field where the soil is dark, very productive and shows crop response on all fertilizer practices. On this field hybrids have made outstanding response for manure, limestone and phosphate and also for sweet clover, residues, limestone, phosphate and potash.

Lodging

Lodging is important as a factor related to plant food utilization. Plants, physiologically weak in root or stalk, are more severely handicapped on fertile soils than on poor soils. Varieties with such inherent weaknesses may be reduced in yield by as much as 20 per cent where conditions promote lodging. Proper fertilization with phosphate and potash is supposed to prevent or aid in the prevention of lodging. However, inherent weaknesses within the plant may inhibit this physiological function of phosphorus and potassium. Inability of many of our open-pollinated varieties of corn to cope with conditions favoring excess lodging has accounted for many losses and has often discouraged good soil treatment practices. On the other hand, hybrids by resisting those influences which cause lodging, give good returns and encourage better soil management. Examples of this are illustrated in Fig. 21. Hybrids themselves may react differently in response to certain fertilizing applications. Fig. 22 gives such an illustration. Two hybrids, both of which lodged badly under the conditions of the experiment when potassium was deficient in the soil, showed a striking contrast in response when potash was applied. Lodging, when occurring, fosters the production of light, chaffy, immature, poor quality and damaged corn in such a way that fertilization cannot entirely overcome. When no lodging occurs, proper fertilization can improve yield, quality and maturity of corn.

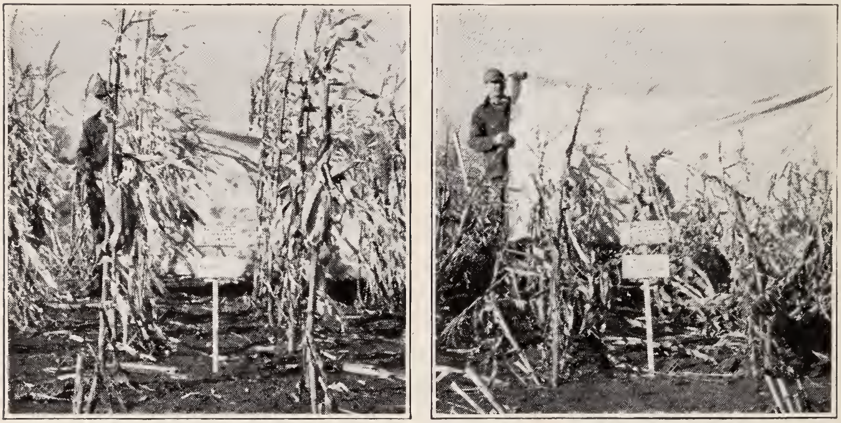

Fig. 21. RESPONSE TO SOIL TREATMENT INHIBITED BY LODGING.

On the right an open-pollinated variety unable to utilize to the fullest extent the advantages of a fertile soil. On the left a hybrid making full use of the available plant food.

Quality

The ability to utilize available plant food in producing good quality corn from fertile farm lands is also an apparently inherent characteristic of the plant itself. Some varieties and strains show this characteristic more than others probably because it is directly related to ear rot resistance. Sometimes an abundance of phosphate and active organic matter in the soil favors the development of certain ear rots. These rots may infect a high percentage of the corn ears. Strains of corn that are susceptible to these diseases are often reduced in yield of sound corn by 10 to 15 per cent. Strains resistant to these defects produce good sound corn with very little or no damaged grain and therefore are subject to little dockage on the market. The economic importance of ear rot resistance in corn to be grown cn fertile soil has been illustrated very clearly on the Dixon soil field where a resistant and a susceptible strain were compared. On an area having been continuously treated with manure, limestone and phosphate over a period of more than twenty years a susceptible strain had almost 100 per cent of the ears and 17 per cent of the grain infected with rot. A resistant strain had less than 1 per cent of the grain infected (Fig. 23).

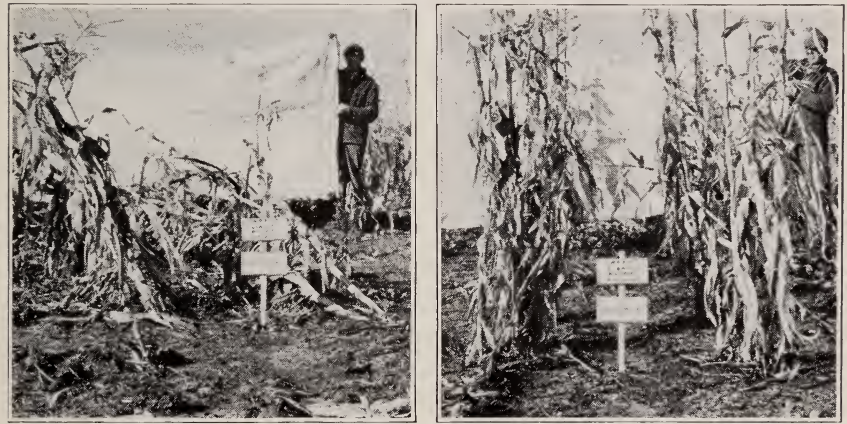

Fig. 22. RESPONSE TO POTASSIUM INHIBITED BY LODGING.

Potassium made the difference in those two hybrids. Without potassium both hybrids were lodged equally as bad.

Drouth Resistance and Stalk Barrenness

Drouth resistance and stalk barrenness are heritable characters of the corn plant which are especially closely related to soil improvement programs under Illinois conditions. Most soil improvement practices include a liberal use of phosphate. Phosphate stimulates early growth and hastens maturity both of which are undesirable influences in extremely dry mid-summer seasons. Growth stimulation produces a large plant requiring maximum water supply at a time when moisture is likely to be most deficient and early maturity cuts off 10 days to two weeks of the plant's production period in early fall when moisture conditions

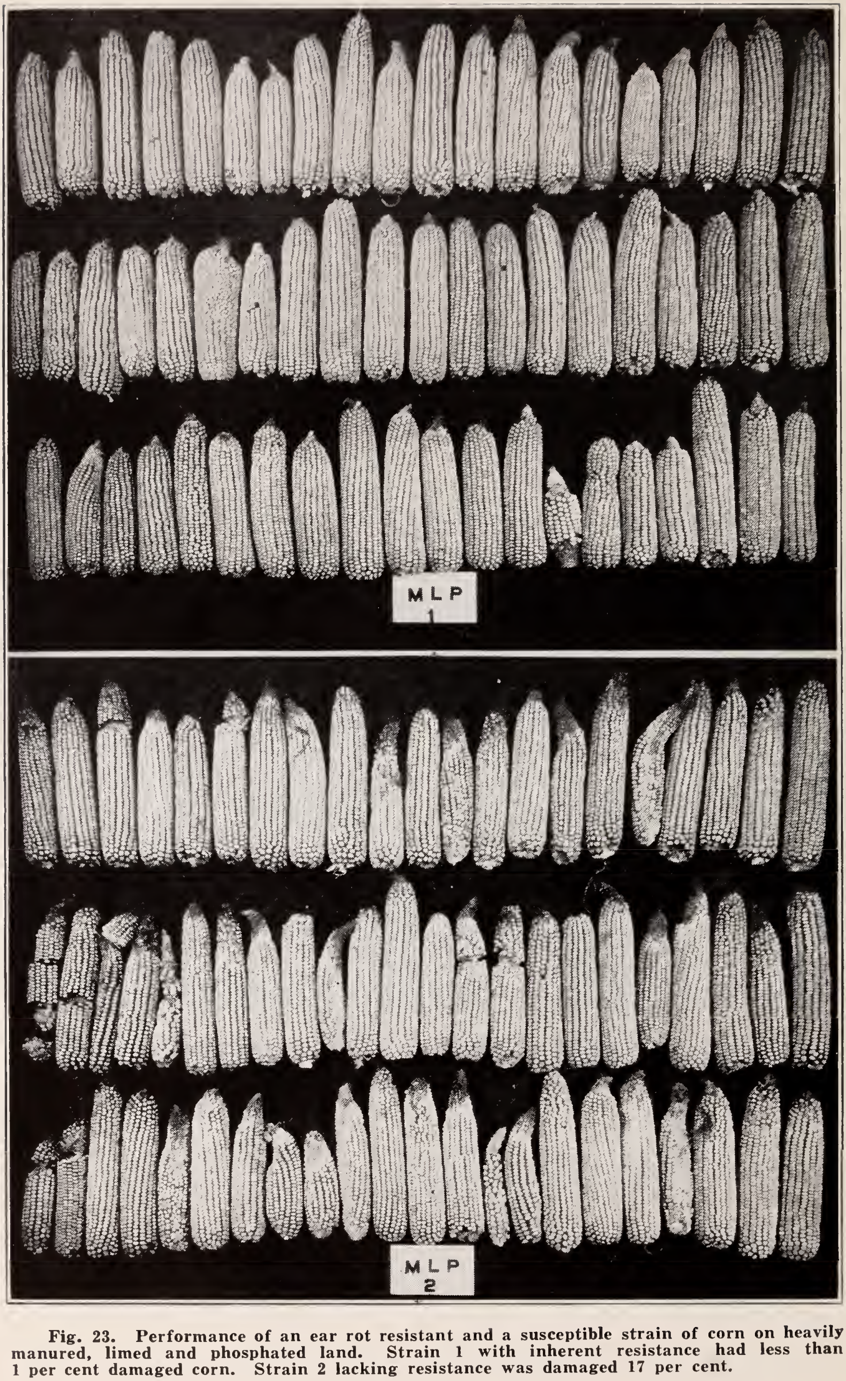

Fig. 23. Performance of an ear rot resistant and a susceptible strain of corn on heavily manured, limed and phosphated land. Strain 1 with inherent resistance had less than 1 per cent damaged corn. Strain 2 lacking resistance was damaged 17 per cent.

are more likely to be optimum in Illinois. Inherent drouth resistance (Fig. 24) enables the plant to withstand very adverse weather conditions in midsummer. By withstanding the adversity of midsummer drouth or early stimulation, corn can continue to normal maturity during the more favorable fall season. When the drouth-resistant character is coupled with the inherent ability to grow an ear on every stalk, the corn plant is prepared to use the plant food from fertile soils to pro-

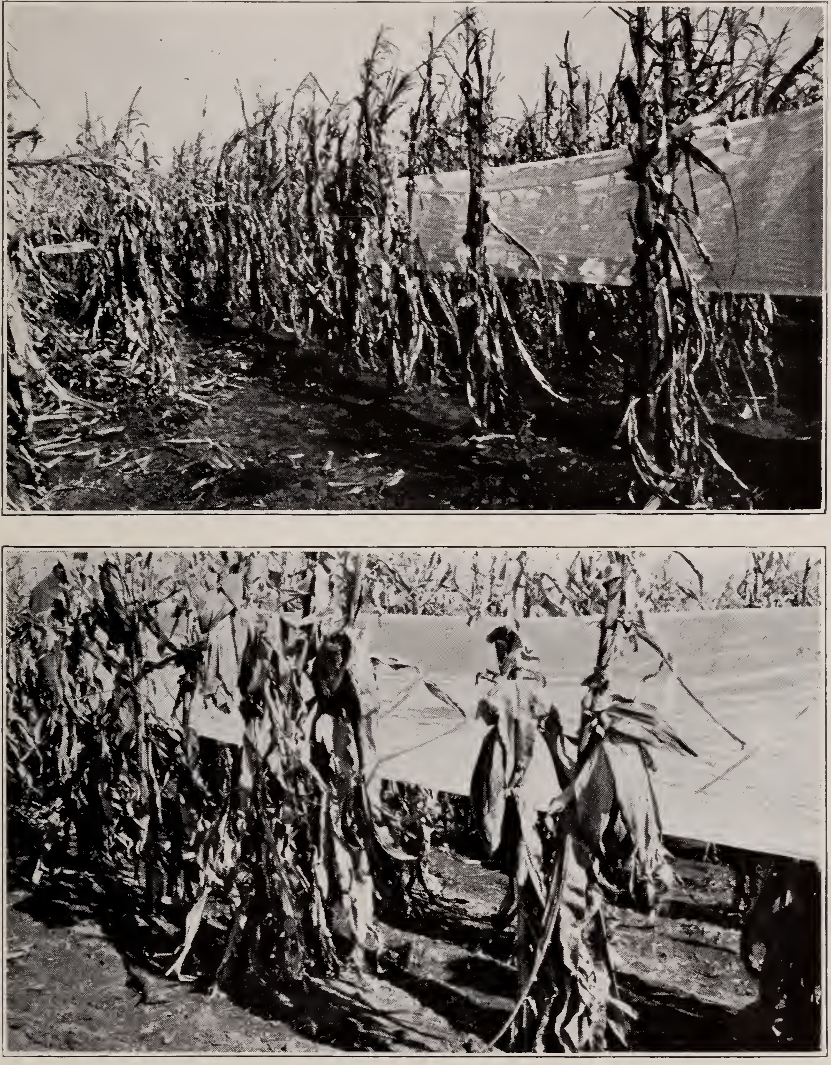

Fig. 24. DROUTH RESISTANCE IMPORTANT ON PHOSPHATED LAND.

At the top Krug corn growing on limed and phosphated land during the drouthy season of 1936 at Kewanee. The yield was 37 bushels of light and chaffy corn. Twenty-seven per cent of the stalks were barren. Below a drouth resistant hybrid which yielded 64 bushels on the same area and had only 8 per cent barren stalks.

duce high yields. At Kewanee during the dry season of 1936, on a heavily limed and phosphated plot a drouth-resistant strain produced 64 bushels of good sound corn an acre. Krug, an open-pollinated variety, produced 37 bushels an acre of relatively poor quality, chaffy corn under the same conditions. Twenty-seven per cent of the Krug stalks were barren but only 8 per cent of the hybrid stalks were barren.

SUMMARY

Although some very interesting research work on crossing corn was conducted before the present century, the work which directly culminated in the hybrid corn industry began 33 years ago when the investigations of E. M. East and Geo. H. Shull were started.

During the past 2 or 3 years there has been a rapid shift from open-pollinated varieties to corn hybrids. It is estimated that more than 5,000,000 acres will be planted to hybrid corn in 1938 in Illinois.

Inbred lines are the building blocks from which hybrids are made. Many years of self-fertilization accompanied by selection both within and among lines are required. Useful lines are those that combine with others to give high yielding hybrids as well as contribute good root system, strong stalk and good grain quality. Hand pollination, aside from being necessary in the production of inbreds, is also resorted to in maintaining purity of inbreds after once produced.

The hybrid corn producer is finding the breeding plot indispensable and is giving considerable thought to planning and handling it.

A single cross is made by crossing two inbred lines, a three-way cross is made by crossing a single cross with a third inbred line, and a double cross is made by crossing two single crosses. Practically all of the commercial hybrid seed corn planted in Illinois consists of double-cross combinations.

Hybrid seed corn is produced commercially by alternating pollen and ear parents in the field and detasseling the ear-parent plants before they have shed pollen. The crossing field is isolated from other corn.

The difference in the response of different corn hybrids to insect attack is becoming widely recognized. Insect resistance is known to be heritable, and desirable hybrids can be developed which will resist specific insect attacks. The problem of insect damage is serious enough to the corn crop of Illinois to justify a special breeding program for insect resistance.

Several inbred lines available at present, while apparently not possessing resistance to all corn insects, do usually show a high degree of resistance to one and in some cases more insects. In these inbred lines it appears that there is little association between the factors that cause resistance to different insects.

Field tests with seed corn dried on hangers and in bins indicate that quick drying produces seed corn having approximately the same value for crop production as that dried slowly on hangers.

The five best hybrids in the 17 performance test fields in 1937 exceeded the five best open-pollinated varieties by an average of 13.6 bushels of sound corn per acre or 18.6 per cent. The average percentage of erect plants at harvest time was 71.7 for the five best hybrids and 49.7 for the five open-pollinated varieties.

Considering only those entries that have been grown for two or more years the results of field tests show that in general performance seven hybrids in northeastern Illinois ranked 15 points or more above the average of the open-pollinated varieties in the test. In northern Illinois 19 hybrids so ranked with respect to the average of the open-pollinated varieties; in north-central, 20; in central, 26; south-central, 15; and southeastern, 2.

Under favorable conditions some hybrid corns produced their best yield at four stalks per hill in rows 40 inches apart, while others gave their best yields at three stalks. Most open-pollinated varieties gave their best yields at three stalks per hill.

Increased thickness of planting resulted in a reduction in size of ears, weight of 1,000 kernels, test weight per bushel, number of ears per stalk, and percentage of erect plants at harvest.

During the past five years the apparent resistance to insect attack of many corn hybrids has been tested in strip test and corn performance test plots throughout the State. These tests have demonstrated that a great range of resistance or susceptibility occurs in the hybrids. Many are more resistant than the commonly grown open-pollinated varieties, but some are more susceptible. In the present report data are included with regard to chinch bugs, grasshoppers, southern corn rootworm, white grubs, and corn earworms.

The data demonstrate that it behooves each farmer to learn the insect resistance of the hybrid which he may be planning to grow during any season when that insect may be abundant. This information is available with regard to many hybrids at the experiment station or from the producers of seed.

Fertile soils are necessary in order to take full advantage of the high yielding ability of good hybrids.

Hybrid performance on infertile soils may be disappointing.

On highly fertile soils, in addition to high yielding ability, and good quality, hybrids should be resistant to lodging, stalk barrenness, damage from insects, disease, drouth and cold.

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